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Memory Functions in Reading
and Arithmetic-Disabled Children

by

Clare F. Brandys

B.Sc. Loyola University of Chicago, 1982
M.A. University of Windsor, 1984

A disseration
Submitted to the Department of Graduate Studies
through the Department of Psychology
in partial fulfillment of the
requirements for the Degree
of Doctor of Philosophy at the
University of Windsor

Windsor, Ontario, Canada, 1988
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ISBN 0-315-43730-8

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ABSTRACT

Two subtypes of learning-disabled (LD) children, with primary deficiencies in Reading (RD) and mechanical Arithmetic (AD) were compared to a group of age-matched normals on several memory tasks. Memory tasks were classified according to type and modality of material input, method of response, phonetic properties and visual features of the material encoded, and stage of memory process required. Results showed a double dissociation between the RD and AD groups: RD children evidenced mild difficulty with verbal memory tasks while AD children exhibited difficulty with nonverbal memory tasks. This latter result was particularly robust, suggesting marked difficulties in nonverbal and novel mnemonic encoding for AD children. In addition, differences were found between groups with respect to the phonetic characteristics of stimuli and response format of memory task consistent with previous research on these LD subtypes. Modality and visual feature variables were not found to effect the performances of the groups in a predictable fashion. The various inter-task differences were discussed in the larger context of neuropsychological functions and academic strengths and weaknesses of the RD and AD groups. Specific remedial recommendations were offered to take best advantage of respective mnemonic strengths in each group.

ACKNOWLEDGEMENTS

I wish to extend my deep appreciation to the many individuals who helped in the various stages of this dissertation process. Dr. Byron Rourke, my advisor for this work and the past five years of my graduate training, has continued to provide me with excellent guidance and support. I extend sincere gratitude to him for the thoroughness of his teaching and for directly inspiring me with his exemplary work in the exciting field of neuropsychology. I also wish to thank the other outstanding members of my committee, Dr. John Fisk and Dr. Douglas Shore, from the Department of Psychology, and Dr. Walter Romanow, from the Department of Communication Studies, who were extremely helpful in regard to methodological and statistical issues and stylistic comments. Dr. Jack Fletcher, my outside reader from the Psychology Department at the University of Houston, offered many helpful suggestions and comments from his extensive knowledge and experience in the fields of neuropsychological research and learning disabilities. Each of these committee members added considerably to the final product through his personal insights into the complex topics addressed here.

I wish to extend gratitude to Dr. Howard Jobin and Dr. Ray Petrauskas and other members of the Psychology Department at the Toronto Metropolitan Separate School Board who were

instrumental in providing me access to and assistance in selecting children as test subjects. Furthermore, thanks are extended to the many school principals, teachers, parents, and the children themselves who cooperated so selflessly and donated their time and energy for the benefit of learning disabled children in general.

On a personal note, certain individuals also deserve important mention. Mr. Darren Fuerst offered considerable friendly assistance with statistical and computer-related problems. As always, my family has remained supportive and encouraging. Finally, a special thanks to my husband and best friend, John Mastrella, who has worked tirelessly by my side, throughout the many months of planning, writing, typing, and re-typing. His patience, strength, and encouragement are priceless gifts.

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Chapter I

INTRODUCTION

The purpose of the present study was to investigate the relationships between various subtypes of learning disability and specific memory skills. In the past several years, it has become increasingly more clear that recognizable subtypes of learning disability exist, distinguishable not only on the basis of academic achievement scores and patterns, but also on the basis of neuropsychological test performance configurations. Neuropsychologists interested in studying the brain-behaviour relationships of learning-disabled (LD) children have carried out extensive investigations in this area, showing that specific LD groups can be distinguished on the basis of auditory-verbal, psycholinguistic, visual-perceptual, problem-solving, and tactile-perceptual abilities.

The great numbers of children showing learning disabilities in reading, spelling, and the related language arts have resulted in a plethora of research and clinical efforts in this direction, now considered to be its own subspecialty within the practices of education and psychology. To summarize briefly the major relevant findings, Q-type factor analysis and cluster analysis research has shown that children with disabilities in reading (RD) frequently exhibit deficits in auditory-verbal and psycholinguistic skill areas, including depressed WISC Verbal subtest scores, (Doehring et al., 1984), impairments on tests of sound-symbol

association (Doehring et al., 1981; Rourke & Finlayson, 1978), letter and temporal sequencing tasks (Denckla, 1979; Doehring, et al., 1981; studies reviewed by Rourke, 1978), naming tasks (Denckla, 1979; Mattis, 1978), and phonemic segmentation tasks (Shankweiler & Liberman, 1979). These deficits are usually found in the context of relatively intact visual-perceptual skills, particularly on tasks involving nonverbal material (Rourke & Finlayson, 1978), adequate nonverbal problem-solving skills (Strang & Rourke, 1983), and well-developed psychomotor skills (Rourke & Strang, 1978). Nonetheless, there is some evidence to suggest that one or more subtypes may exist which display deficiencies on certain visual-perceptual tasks as well (Boder, 1973; Mattis, 1978). In an excellent review of many areas of RD research, Rourke (1978) underscores the importance of considering the multi-faceted neuropsychological deficits which may underly different cases of this academic deficit.

The development and use of more sophisticated multivariate statistical tests has made it possible to study more specific subtypes within the RD heading. While these unique RD subtypes have been differentiated in their performances on specific neuropsychological measures, the general conclusion appears to be that the majority of RD children are impaired, to a lesser or greater degree, on tests assessing auditory-verbal and psycholinguistic skills (Lyon et al., 1982; Petruskas & Rourke,

1979). Such findings are usually interpreted as suggestive of left hemisphere dysfunction (Jorm, 1983; Rourke, 1978, 1982; Rourke et al., 1983).

Similarly, children with disabilities in spelling have been shown to exhibit deficits on auditory-verbal and psycholinguistic tasks believed to be subserved by the left cerebral hemisphere (Sweeney & Rourke, 1985). One of the few extensive studies examining children with spelling disabilities reports that these children can be differentiated into two types: one making predominantly phonetically-accurate (PA) errors in spelling, the other making predominantly phonetically-inaccurate (PI) errors (Sweeney & Rourke, 1978). These two groups were also found to display different weaknesses on a battery of neuropsychological tests. To summarize, PA spellers generally fare better than PI spellers who display deficits on a variety of tests tapping auditory-receptive skills, suggestive of handicaps in basic psycholinguistic functioning. While PA spellers perform in a manner similar to normals on simple psycholinguistic tasks (requiring brief, single-word responses), they perform in a below-average fashion on tasks requiring complex linguistic encoding and analyses and the ability to associate the spoken word with visual-spatial information. PI spelling was found to be associated with serious RD; deficits in both reading and spelling are thought to be related to debilitating deficiencies in basic

verbal skills. While PA spellers were found to be superior to the PIs in reading performance, they also displayed mild to moderate reading retardation, particularly at older age levels. Further research on these two spelling subtypes suggests that PA spellers are limited in both reading and spelling by following too strictly a phonetic approach to word decoding (Corderre, Sweeney & Rourke, 1979).

This consideration of the spelling-reading relationship raises another important issue relevant to the LD-memory research and the present study. Namely, the majority of LD children present with deficits in more than one academic skill, making it quite difficult to study isolated "specific" academic disabilities. In addition to the relatively circumscribed reading-spelling-disabled groups just reviewed, a great many LD children suffer retardation in reading, spelling, and arithmetic. Rourke and his colleagues have differentiated these children as Group 1, in contrast to Group 2 (showing relatively good arithmetic achievement and poor reading and spelling skills). Both groups have been shown to perform in an impaired fashion on tests assessing auditory-verbal and psycholinguistic skills, while Group 1 children perform worse than Group 2 children on tasks of verbal-associative skill (Rourke & Finlayson, 1978). Unlike Group 2, Group 1 children also show evidence of deficit in certain areas of tactile-perceptual learning (Rourke & Strang, 1978). For the

most part, both Groups 1 and 2 appear to be fairly adept at the processing of visual-spatial information, in contrast to children showing relatively poor mechanical arithmetic skills (Group 3) ((Fisk & Rourke, 1979; Rourke & Finlayson, 1978). Further examination into the subtypes of Group 1 children suggests that certain groups may also exhibit mild motor and psychomotor deficiencies (Fisk & Rourke, 1979).

In contrast to children with disabilities in reading and spelling, children with relatively poor mechanical arithmetic skills yet good reading and spelling achievement have been the subject of much less research. Nonetheless, several fairly consistent results can be summarized in regard to arithmetic-disabled (AD) youngsters: In direct contrast to RD children, AD children frequently exhibit well-developed auditory-perceptual and verbal-related skills, but deficient visual-perceptual-organizational skills (Rourke & Finlayson, 1978). As well, Rourke and Strang (1978) have demonstrated bilateral impairments on tests of psychomotor and tactile-perceptual skill; these were found to be somewhat more marked on the left side of the body. Furthermore, on a test of complex nonverbal reasoning skills, AD children have been found to perform in a below-average fashion (Strang & Rourke, 1983). These findings are generally interpreted as suggestive of dysfunctional right hemisphere processes (Rourke, 1982), in the context of well-developed left hemisphere

(language-related) functions.

In this exploration of LD children's strengths and weaknesses, one facet of higher-order neuropsychological skills which has been largely overlooked in the study of LD subtypes is memory ability. While literally hundreds of studies have been undertaken in the last several years exploring the relationship between memory skills and general and specific reading disabilities, very little work has focused on the interrelationships between specific reading, spelling, and arithmetic disabilities and memory skills. The unique configurations of other neuropsychological strengths and weaknesses associated with specific reading and arithmetic learning disabilities suggest that such children may be expected to display unique differences in the realm of mnemonic functions. In keeping with the other neuropsychological findings, these differences were expected to obtain on the basis of modality of input (primarily concerning the auditory vs. visual distinction), response modality, and symbolic nature of material (verbal vs. nonverbal).

First, it is worthwhile to summarize the general processes involved in memory, from both an information-processing and neuropsychological perspective:

A. Memory Definitions and Models

For the purposes of the present study, Russell's general definition of memory will be accepted:

a persistent central nervous system change consisting of both environmental information and activities of the organism that can be reproduced by the organism after some interval of time in an exact or equivalent form.

(1981, p. 281)

The process of memory appears to involve at least four stages. The first is the input and encoding stage; this involves both the "data-driven" automatic detection and registration of information arriving through the various senses and the "conceptually-driven" allocation of attentional resources of the limited capacity memory system (Lindsay & Norman, 1977). Broadbent (1958) first conceptualized this selectivity of attentional resources as a "bottleneck" filter linking the pre-attentional sensory store ("s system") with the store of conscious awareness ("p system"); it is believed to be the first point at which some information is inevitably lost due to the limited capacity of the input channels.

The next two stages involve processing to a limited capacity (7 ± 2 chunks, according to most sources - Zechmeister & Nyberg, 1982) short term store and an unlimited capacity long term store. In order for material to be maintained in the former, it appears to

require rehearsal or other forms of active processing; for this reason, the short term store is commonly referred to as "working" memory. The neuropsychological counterparts of these information-processing constructs are believed to be twofold: (1) A central nervous system change occurs on the neuronal level. The areas of maximal involvement in the brain appear to be localized in the reticular activating system, particularly the diencephalon (involved in alertness, directed attention, and initial encoding) and the medial temporal lobes (involved in consolidation and storage) (Winocur, 1984). (2) Next, there is maintenance of this change in the central nervous system, probably involving complex biochemical changes (Russell, 1981).

The final step in the memory process involves retrieval and output. Research into normal human memory strongly suggests that output is related in some consistent way to input. Many studies have illustrated the need for retrieval cues to be presented or transformed into the same sensory modality as information was originally presented in order to be effective (e.g., Lehman, 1982).

Among the neuropsychological theories is the notion of separate memory systems, one visual, one auditory, or one semantic memory system with multiple access routes (Paivio, 1971). Rosinski, Pellegrino, and Siegel's (1977) work with normal

children supports this latter hypothesis, with somewhat longer "semantic access" processing time required for verbal information than for pictorial (nonverbal visual) information because of the extra acoustic-phonemic coding step involved in the former. Similarly, research suggests that recall can be disrupted by interpolated activity in the same modality as a memory task (Brooks, 1968). Numerous researchers have likened these mnemonic processes to the left (verbal-phonemic) and right (spatial-pictorial) cerebral hemispheres (Bower, 1972; Seamon & Gazzaniga, ~1973). The logic which follows is that specific deficits in verbal-memory exhibited by RD children are related to left hemisphere dysfunction, specifically in the left inferior parietal lobe (Jorm, 1979).

Next, it is important to consider the LD-memory research collected from both clinical and research sources.

B. Reading Impairment and Memory Functions

The importance of short- and long-term memory in both the acquisition and development of reading skills is well recognized and discussed in most conceptualizations of both the reading process and reading disabilities (e.g., Doehring, 1985).

In an interesting review paper on the relationship between memory and reading abilities, Torgeson discusses the central

cognitive link of these two processes:

... information processing models of cognition ... describe a central role for memory processes in the sorting and manipulation of information which occurs during intellectual activities. Both relatively short and long term 'memories' are seen to be necessary for such activities as storing information temporarily while it is being processed, and for retaining information over longer periods so that it may be used in the future... It is not surprising that most of the recently developed models of reading also specify an important role for a variety of memory functions. (1979, p. 58)

The memory functions involved in the reading process are believed to include an initial sensory visual trace of the printed word and concomitant iconic image stage in which the visual input is compared to stored visual images. Torgeson views this as the point at which visual information is transformed into its verbal (phonemic) code, thereby allowing for several chunks of information to be encoded simultaneously. The next and, perhaps, most critical stage for RD children is the short term or working memory stage during which units of verbally-coded information are stored temporarily in order to process whole sentences to extract meaning. Jorm further elucidates the processes the reader undergoes during this working memory stage:

... [he must] remember the phonemes which result from applying each grapheme-phoneme correspondence rule and the order in which the

phonemes are to be output. He must also remember which letters of the word he has already analyzed so that he will avoid going over letters which have already been accounted for, or omitting strings of letters which have not. (1979, p. 25)

Baddeley (1978) has described the process of auditory-verbal short term memory in reading as primarily involving an articulatory loop. (At this stage, phonological confusions may arise if phonetic codes are not well established.) The other component of memory is considered to be a central executive which controls the articulatory loop. In accordance with Paivio's (1969) dual code theory of memory, a corresponding 'visual spatial scratch pad' (Baddeley & Hitch, 1974) has been proposed to account for visual nonverbal memory representations; this is also believed to be controlled by the central executive.

Finally, long term memory functions are believed to be involved when the individual accesses semantic stores to derive meaning from sentences, paragraphs, and larger units of text. Long term memory is also believed to be accessed by a reader when he encounters new information which is then compared against and associated with already-stored engrams. (The corresponding working memory procedures in children learning to read is the temporary storage of spelling patterns in order to process a whole word at a time. Long term memory is then involved in matching

words to permanently stored feature detectors. Only after these stages have become automatic are beginning readers able to associate meaning with larger units of written material.)

C. Review of RD - Memory Studies

The following sections summarize the research relating to memory task performances of RD children. A distinction has been made between clinical and experimental research, due to differences in memory instruments, paradigms, and theories employed. For the most part, the experimental research appears to be superior to the clinical studies in its tendency to employ stricter hypotheses based on current cognitive psychology conceptualizations of the memory process.

However, the experimental research is fraught with specific methodological flaws, particularly those pertaining to subject selection criteria, which are usually controlled for in the clinical research. Although commonly-accepted measures of reading (e.g., tests of word recognition, reading comprehension, and/or teacher reports) and cut-offs for reading impairment are usually used, researchers conducting experimental studies have sometimes overlooked other clinical difficulties in their sample selection. Among these difficulties are failure to control for intellectual (discussed in Torgeson, 1985), gross sensory, and/or emotional differences (as proposed by Rourke, 1975, in his definition of

specific learning disabilities), although it is becoming more commonplace to control for one or more of these variables. Furthermore, most studies from experimental laboratories continue to fail to separate groups on the basis of other learning difficulties. Thus, the children composing the RD groups studied may or may not also exhibit learning disabilities in spelling, mechanical arithmetic, or writing. The dangers in combining heterogeneous subtypes of learning disability for study lie in the possibility that one may overshadow performance differences unique to each subtype by calculating group means (effectively 'cancelling out' intra-group differences).

1. Research - Clinical Sources

Research emanating from clinical sources has commonly taken the form of analyzing a large number of test variables in a clinically-derived subtype of RD children. Among the tests used have been Benton's Sentence Memory Test, ITPA memory subtests, Wechsler's Digit Span and other clinical instruments believed to measure the construct of memory. Clinical researchers have shown that one or more subtypes of RD children are deficient, in comparison to control subjects or test norms, with respect to immediate auditory-verbal memory (WISC Digit Span subtest - Rourke & Finlayson, 1977; Auditory Attention Span subtest of Detroit Tests of Learning Aptitude - Lyon, et al., 1981; Auditory-Sequential Memory Subtest of ITPA - Stanley, 1975),

auditory memory for strings of meaningful information (Benton's Sentence Memory Test - Rourke & Finlayson, 1978), and visual memory for nonverbal designs (Memory for Designs Test - Lyon, et al., 1981; Benton Visual Retention Test - Lyon, Stewart & Freedman, 1982).

Similar to the evidence collected with the auditorially-presented Digit Span subtest, RD children perform more poorly than control subjects and other LD children on a relatively-new clinical tool, the Visual Auditory Digit Span (VADS - Koppitz, 1975). However, evidence suggests that RD children may not be distinguishable from emotionally disturbed children in their performances on this test (Koppitz, 1973).

Generally, the studies just described are similar in their tendency to employ already-standardized tests to distinguish between clinically-derived groups of children. Despite the statistical advantages of such an approach, one difficulty inherent in this approach is a failure to consider other variables believed to be relevant to memory ability, such as delay between stimulus and response, mode of stimulus presentation, type of response, format of test (e.g., recall vs. recognition), and method of scoring. As well, other possible intervening factors are not taken into account. For example, it has not been ascertained whether differences between RD and normal readers obtain on a task such as Digit Span

because of differences in memory skill, or because of deficits in auditory attention, verbal expression, sequencing ability, or a combination of other underlying skills. Digit Span and several of the other well-standardized tests appear to tap into a variety of skill areas, only one of which may be memory ability. Torgeson (1979) has addressed another shortcoming to this 'psychometric approach' - namely, the poor test-retest reliability of the tests used and other possible statistical factors underlying such discrepancies.

2. Research - Experimental Sources

The large body of experimental research exploring the relationship between RD and memory functions has revealed some significant findings, separating these children from their normal age-mates. In general, groups of RD children at various ages have been shown to have significant auditory-verbal memory difficulties, particularly for serialized material. Holmes and McKeever (1979) attribute Orton in 1937 with the earliest mention of a basic serial verbal deficit (both auditorially and visually) as a symptom of dyslexia. RD children's performances on both auditory and visual tasks, involving both verbal and nonverbal material, have been studied extensively and are presented here in accordance with type of task used:

a. Verbal studies - auditory modality

Perhaps the simplest experimental research supporting the auditory-verbal deficit position stems from work with dichotic digit tasks (McKeever & VanDeventer, 1975). In this study, RD children were impaired, in comparison to normal controls, in their ability to recall three sequential digit pairs delivered to the ears in simultaneous fashion. Both right- and left-ear recall scores were lower for RD subjects. However, the poorer performances reported for the group of RD children in this study did not distinguish as to whether the difficulties relate to short term recall tasks in general, or sequential memory tasks specifically. It is also important to note that no differences obtained when comparing groups on left ear and right ear recall; all subjects showed a significant right ear advantage, implicating normal left-hemisphere language specialization across groups.

Continuing along these lines, auditory-verbal memory skills have been investigated in relation to the serialization of stimuli. Using both auditory-verbal (digit strings) and visual-nonverbal (Corsi blocks) tasks for comparison purposes, Corkin (1974) found a generalized serial deficit in three age groups of RD children "that cuts across sensory modalities". Similar findings have been reported from other RD serial memory studies (Mann et al., 1980; Ritchie & Aten, 1979), suggesting that serialization of stimuli has a significant effect on the recall of auditory-verbal information.

Studies of normal human memory indicate that there are separate representations of item and order information in memory (Martin, 1978). Nonetheless, Corkin's broad generalization regarding the existence of RD serial-order deficits requires some clarification, for performance differences between the groups obtained only under conditions of delayed recall. Thus, the question still remains as to whether the memory deficits are related to poorer long term retention/recall, poorer serial ordering, or a combination thereof. Corkin's scoring methods do not allow for separate analyses of these subskill processes.

Another study which has examined specifically this sequential information processing issue utilizes the popular sequential versus simultaneous distinction (Luria, 1966). Das, Leong, and Williams (1978) compared normals, a heterogeneous group of "LD" children, composed of both "hypo-" and "hyperkinetic" youngsters, and a (relatively) homogenous group of children exhibiting reading disabilities on a number of sequential recall and simultaneous processing tasks (Raven's Progressive Matrices, Figure Copying Task). Factor analysis of the group scores suggested that the same patterns for processing information exist in the three groups, except that the LDs and RDs are at lower performance levels. The finding relevant to the present review was that the RD group performed especially poorly on both the simultaneous and sequential memory tasks. The relevance of the cognitive and

behavioural deficits in the non-specific LD group's performances requires further study.

Another investigation compared auditory-verbal and visual-nonverbal (pictorial) memory sequential span (Lindgren & Richman, 1984) while varying mode of response ("visual"= pointing, "verbal"= naming stimuli orally). In both younger (age 8) and older (age 12) RD groups, intramodal (same response as presentation modality) verbal-memory deficits predominated. In addition, partialling out the effects of memory -for-content and order-memory, in turn, revealed that RD children's errors were largely confined to serialization problems. Intermodal memory difficulties were found in the younger, but not the older RD age group, suggesting that verbal mediation deficits may contribute significantly to the early RD clinical picture, disappearing as the child matures. At later ages, the verbal-material, auditory-modality memory problems appear to persist, posing practical limitations for both academic and non-academic tasks. Along these lines, Young (1971) has shown that order of presentation of visual and auditory tasks may affect performance, particularly in RD subjects. However, this difference between RDs and normals diminishes with age. These studies present examples of several methodological manipulations (including the developmental nature of comparisons) which can strengthen a clinical research design, thereby more thoroughly exploring the

skills which underlie memory impairments in RD children.

Other researchers have made the distinction between short-term recall processes and long-term storage capacities in their research designs. Byrne and Arnold (1981), for example, report that RD and normal readers performed equally well on a free recall task, regardless of presentation rate and position of stimuli; both RD and Control groups showed a "clear and substantial" recency effect (for later-presented items on the list). However, the poor readers evidenced much lower WISC Digit Span scores. The authors suggest that the "storage facilities" *per se* are unimpaired in RD children and that short-term "control processes" may be the distinguishing variable between groups. These researchers fail in overlooking another important variable, that the free recall and digit span tasks are not equivalent; for example, the requirement of keeping stimuli ordered in the digit span task dictates that different cognitive skills be utilized in the two tasks.

Using an auditory-verbal memory-span sensitive "partial report" technique, Cohen and his associates (1984) conducted a well-designed study to address several important questions: (1) Does the short-term memory/ reading skill relationship evident in RD children extend upwards to very good readers? and (2) Do younger normal readers perform similarly to their older RD

counterparts (matched for reading ability) on memory tasks -- i.e., are the RD memory difficulties due to a lag or deficit in processes? For this study, four groups of children were used: RD, normal, and superior readers in grade 5, and grade 3 children equated with the RD group for reading ability. The memory task consisted of listening to taped nine-digit lists, followed by a letter, A, B, or C, indicating that the child was to recall the first, middle, or last three digits of the list. Results showed no inter-group differences with primacy recall (first three digits), but did show differences in medial and recency recall, with the RD group performing most poorly and the superior readers performing the best. The younger normals performed most similarly to their older RD counterparts, suggesting a lag of 'memory skill' development in the RD group. However, the author's postulation that impaired serial phonological processing accounts for both reading and short-term memory deficits is rather inconsistent, as such processes are undoubtedly neurologically-based as this would, in turn, suggest that normal readers are neurologically impaired relative to superior readers.

b. Memory and phonetic recoding

The following research directly addresses the issue of the underlying basis of auditory-verbal memory deficits as it relates to the capacities for phonetic encoding/recoding in RD and normal readers. Specifically, it appears that the ability to recode verbal

(auditorially or visually presented) material into its phonetic form is deficient for RD children, as demonstrated in the following studies.

Lieberman, Shankweiler, and their colleagues (Brady, et al., 1983; Liberman, et al., 1982; Mark, et al., 1977; Shankweiler & Liberman, 1979) have carried out a series of experiments using both auditory and visual stimuli in which they utilized lists of letters or words and a recall or a forced-choice recognition task. Among the letters and words to-be-recalled or in the recognition-probe phase of the tasks were rhyming-letter and rhyming-word foils, thereby tapping into phonetic encoding/recoding strategies. Poorer recall and recognition scores for nonrhyming words and letters were found in the RD group, suggesting poorer overall retention or retrieval capacities. In addition, the variable of interest, phonetic similarity, discriminated between the two groups. As predicted, RD children made fewer phonetic errors than normals with the rhyming foils. With such material, fewer errors actually represents a poorer performance, suggesting a lack or inefficient use of "internal" phonetic representations of letters and words. (Phonetic recoding abilities have been found in normal children as young as age four [Alegria & Pignot, 1978].) This effect has also been shown in a useful line of predictive research indicating that kindergarten children who are less affected by rhyming foils often become poor

readers in grade 1, with the opposite holding true for good readers in grade 1 (Liberman & Mann, 1981).

This type of research, in its thorough comparison of test format (recall, recognition), modality of presentation (auditory, visual), and use of increasingly more complex stimuli (letters, letter series, words) represents a useful model for experimentation on carefully-selected LD groups. As in other experimental research, however, no mention is made of other learning abilities in the subjects, suggesting that tighter criteria may need to be applied in subject selection.

In contrast to the studies just discussed, RD children have been found to perform at a level similar to normals when the stimuli are nonspeech sounds (Brady, et al., 1983). This finding suggests that the phonetic difficulties are not a result of simple auditory-perceptual problems, but rather are material-specific to verbal information. Along these lines, Ridgely (1970) has shown that younger RD children perform more poorly than normals on a rhyme-production task, implicating that more general phonetic difficulties may form the basis of the memory deficits reported above.

Further evidence suggests that phonetic recoding skills do develop in RD children, but at a slower rate (Siegel & Linder,

1984). Olson et al. (1984) have shown contrasting developmental trends in RDs and normals. While the effect of phonetic confusability increases with age in RD children, it decreases in normals, suggesting "greater precision of phonetic codes" (p. 202). The RD findings suggest a lag in phonetic recoding processes, rather than a permanent deficit in this skill area.

The phonetic confusability findings were extended to sentence recall tasks for purposes of ecological validity. Mann et al. (1980) utilized sentences and agrammatic word strings with and without confusable (rhyming) words. Second-grade poor readers (perhaps only low-average, as selection was made on the basis of class standing, rather than achievement test results) and good readers were asked to recall orally-presented stimulus sentences and word strings after a short delay. Good readers performed in a superior manner on non-rhyming stimuli; however, this difference diminished completely with rhyming stimuli.

c. Verbal studies - visual modality

Further research into RD children's memory abilities using visual-verbal material suggests that a failure to mediate behaviour verbally, in the form of slower or less-efficient labelling skills, contributes to poor performances on certain memory tasks. This effect is particularly pronounced on tasks using novel, less-easily named stimuli. The need to recode from

visual to phonetic form appears to be central to the memory requirement of the reading process:

The perceiver, whether functioning as reader or hearer, must hold a sufficient number of shorter segments [words] in memory in order to apprehend the longer segments [sentences]. Obviously, if he had a span of only two words, the perceiver's comprehension of connected discourse would be extremely limited. But does the reader form a different kind of memory representation than the hearer? Although we do not rule out the possibility that read words can be held temporarily in some visual form, we have indicated reasons for supposing that the reader typically engages in recoding from script to some phonetic form

(Shankweiler & Liberman, 1979, p. 300)

Evidence against simple visual-verbal deficits as a basis for reading disability can be inferred from the paucity of RD in Japanese children who use the Kanji reading system, a non-phonetic system based on graphic/semantic correspondence (Makita, 1968). This study does not discuss the incidence of RD in Japanese children learning the Kana (phonetically-based) system, although other work suggests that the visually-complex Kanji symbols are easier to learn than Kana syllables (Steinberg & Yamada, 1978/9). Bouma and Leguin (1980) suggest that English-speaking RD children require more time to recode a visual stimulus into its name for recall purposes, and even more time to

recode it into its phonetic form for oral reading purposes. Research using visual-verbal material (words, nameable pictures) indicates that poor verbal mediational skills may account for some of RD children's difficulty on tests of visual memory.

Based on their findings that the visual decay rate is equivalent in normal and RD children, but that the RD group is slower and less accurate at verbal labelling of visual items, Ellis and Miles suggest that

... the visual information processing deficit in dyslexic children lies neither in the speed of production, capacity, or speed of decay ... the dyslexic children demonstrate the problems at a name coding level. (1978, p. 567)

Ellis (1981) has further shown that this naming difficulty encompasses problems on both lexical (whole word) and phonological (non-word sound patterns) levels, in the face of unimpaired articulation abilities.

Comparing memory task performances with visual-verbal and visual-nonverbal stimuli, it has been shown that the addition of an interpolated task between stimulus and response can adversely affect RD performances (Done & Miles, 1978). However, this decrement was found only with visual-verbal material, suggesting a specific recoding deficit rather than generalized difficulties

with visual rehearsal. Lunzer (1978) has shown that the poor visual serial-memory skills of RD children and adults can be improved when given longer stimulus presentation time, whereas controls do not improve given this manipulation.

Similar to the work done on auditory-verbal memory abilities, Holmes and McKeever (1979) attempted to distinguish between the specific skills of word recognition (content memory) and serial word recognition (order memory). They also examined these skills with nonverbal stimuli (faces) for comparison purposes. Results showed that RD and normals were differentiated only on their performances of the serial verbal task, with the RD group obtaining significantly lower scores. They interpret this as evidence of a serial "material specific" deficit in older RD children. They cautiously refrain from generalizing their results to younger RD children who may present with a variety of visual-perceptual and visual-spatial deficits interfering with initial reading acquisition skills. Nonetheless, other work has shown visual-sequential memory to be a fairly accurate predictor of reading skill in young subjects (Goldberg & Shiffman, 1972; Lunzer, 1978).

In contrast, using a visual continuous recognition task, Liberman et al. (1982) have found verbal-memory deficits extend "beyond serial order alone". However, this study's use of different

verbal and nonverbal stimuli (CVC trigrams instead of words, designs and faces instead of faces alone), and a different task paradigm, renders direct comparison to other studies questionable. The consistent finding of impaired performances with visual-verbal material in the context of normal visual-nonverbal memory is noteworthy, nonetheless.

Further data relating to this issue are provided by Mason, Katz, and Wicklund (1975). These researchers presented RD and above-average readers with sequences of letter tiles and, after a delay, asked them to recall the exact order (not content). Groups performed equally well with 4-letter strings, but significantly lower scores were found in the RD group with 6-letter strings. When asked to recall 'supraspan' lists of either eight digits or consonants, normal children performed better with each type of stimuli. Partial correlations of reading ability with (a) order, and (b) content memory resulted in higher correlations with order memory, as suggested by other research. As well, RD children were found to differ in the types of errors made, with a greater tendency to make intrusion errors; the authors suggest that RD children use a "less constrained memory set", perhaps because they fail to utilize or understand positional redundancy information (similar to common rules of spelling and word pronunciation).

d. Semantic memory

On the positive side, studies exploring RD and normal children's memory-for-meaning have found that few, if any, differences obtain. While verbatim recall of visual or auditory-verbal information is often impaired in RD groups, semantic memory measures show little inter-group differences. Progressing to linguistically-complex material (and, probably, more relevant to real-life memory requirements), Perfetti and Goldman (1976) tested memory-for-discourse in RD and normal children. Whereas all of the aforementioned studies have used word-recognition tests or teacher reports as measures of reading difficulty, the selection criteria for the RD group in this study was a low score on a test of reading comprehension; thus, the generalizability to other groups studied may be questionable. The RD group in this study performed in a similar fashion to normals on a probe digit span test, but in an inferior manner on a probe discourse task. (This involved the reading of various types of sentences, followed by a probe word from each sentence indicating that the child was to respond with the word immediately following.) The authors contend that these children are limited in the capacity or use of the working memory stage, in which they analyze complex linguistic input. They also caution that some of the deficits found in the RD group may be attributable to vocabulary limitations, a third variable which might account for both reading comprehension and verbal memory deficits. This illustrates an important point

often overlooked in the literature -- namely, failure to consider other intervening variables which may contribute to difficulties on the memory task at hand.

Further evidence relating to the semantic aspect of memory skills stems from a study by Mann et al. (1980) described previously. Interestingly, variations in the meaningfulness (sensibility) and syntactic structure of the auditory-verbal sentence stimuli affected RD and normal groups equally. Such a finding suggests that RD children at young ages are relatively unimpaired in semantic and grammatical aspects of auditory-verbal memory in comparison to their normal counterparts. The relationship between meaningfulness of material and semantic encoding skills has been demonstrated elsewhere (e.g., Tobey, et al., 1982).

Using a traditional logic-based 'semantic integration paradigm', Waller (1976) chose stimuli consisting of several statements forming a story in which true and false inferences were possible (e.g., given the three sentences 'The bird is inside the cage.', 'The cage is under the table.', 'The bird is yellow.', a true inference would be 'The yellow bird is under the table.' while a false inference might be 'The yellow bird is on top of the table.'). Specifically, he hypothesized that normal readers would make more errors than RDs on true inferences, due to the general finding

from other research (e.g., Oakhill, 1982) that normal children engage in more active construction of meaning while reading. In addition, grammatical aspects of the stimulus sentences were varied (number change of subject: singular/plural, tense change of verbs: past/present) to test the prediction that good readers would make fewer errors because of their grammatico-linguistic superiority. Results showed that both good and poor readers incorrectly recognized true inferences (i.e., thereby making semantically-correct errors); this was slightly more prevalent in the RD group, although this trend was not as robust as in other similar studies using an auditory presentation (Paris & Carter, 1973). RD children also committed more number- and tense-change errors. These findings suggest that these children, in spite of greater difficulty with verbatim verbal-sequential recall, are relatively unimpaired with regard to semantic processing and recall. Waller hypothesizes that poor readers may rely more strongly on visual codes for reading-recall, while good readers store information through an abstract verbal code in which grammatical features can be stored more precisely.

Corroborating these results are those of Wiig and Roach (1975) who report that LD subjects (including reading, language, and/or arithmetic-disabled adolescents) had more difficulty with verbatim recall of semantically-irregular (e.g., 'Colorless green ideas sleep furiously.') and syntactically-irregular sentences (e.g.,

'She has washed plastic red small eight cups.'). although they performed in a similar manner to normals when these linguistic constraints were presented correctly. A qualitative analysis of errors revealed that LD subjects were more prone to make word-omission and substitution errors, suggesting inadequate recall of specific terms. Unlike normals, they made few errors normalizing deviant sentence structures (e.g., changing the above stimulus sentence to 'She has washed eight small, red plastic cups.'). suggesting that they fail to code surface linguistic structures as readily as normals. These researchers interpret their results as evidence of separate short- and long-term storage capacities, with RD limitations in STM (grammatical form) while LTM (semantic form) functions remain intact. Other research supports this notion of RD memory difficulties with sentences presented in irregular grammatical form. These problems are perhaps attributable to RD children's inability to (1) predict word order in sentences, and (2) to limitations in grammatical knowledge (Weinstein & Rabinovitch, 1970). Torgeson (1985) has discussed at length the possible effects of limitations in RD children's knowledge bases, thereby making new information less personally meaningful.

e. Nonverbal studies

Although RD children appear to have no difficulty in making simple visual (pictorial) matches (no memory involved), impair-

ments have been found with a delay as short as one second between first and second stimulus presentations (Cummings & Faw, 1976). Nonetheless, these researchers report that RD performances did not deteriorate any further at longer delay intervals, nor could specific deficits for serial information be found. Similarly, using well-controlled tachistoscopic presentations, Goyen and Lyle (1973) have found that young RD children performed more poorly than their age-matched controls in making simple same-difference judgments after a 5-second delay. An analysis of their performances indicated that RD children obtained more errors with equivalent items, although they performed similarly to controls on non-equivalent items. This finding suggests that their differences on the task cannot be attributed to faster visual decay (which would have resulted in more errors of each type), but that they are, more likely, related to failure in detecting details, either in the initial input stage or when making discriminative judgments for responding.

Nonverbal studies not relying on verbal encoding skills generally suggest equivalent skills in normal and retarded readers. Kastner and Rickards (1974) employed a task consisting of recalling sequences of pictures which had been pointed to in digit-span fashion. Both novel and familiar visual stimuli were used to test the notion that RD children are deficient only in their ability to recode visually-presented information into its verbal

form (i.e., by naming stimuli internally). RD children were found to perform normally when asked to recall sequences of the familiar stimuli, suggesting that they can and do apply simple verbal labels to visual stimuli. However, on the less-easily named novel nonverbal stimuli, RD children performed more poorly than normals. From subjects' reports upon questioning, it was learned that RD subjects tended to switch from a verbal to a less-efficient 'visual' (nonverbal, it would appear) strategy on the novel task, while controls devised their own verbal codes to use on the novel task. Kastner and Rickards suggest that RD children are not deficient in their general ability to mediate verbally, but rather in their ability to do so in a flexible, effective way.

Other research has looked into the role which reinforcement can play in memory test performance. The crucial element appears to be the interaction between type of reinforcement used (concrete rewards, verbal feedback) and the difficulty level of the task under consideration. In a first experiment, Goyen and Lyle (1971) found concrete incentives (money) had no effect on either RD or normal children in their performances of a nonverbal visual recognition task. However, when the visual stimuli were made more discriminable and were shown for longer exposure periods (thus making the task easier for subjects), significant improvements were observed for RD and normal children given positive incentives. Otto (1961) also reports that verbal feedback

reinforcement interacts significantly with grade placement to produce improvements on a paired associate task in older subjects. This effect was found equally for poor, average, and good readers.

f. Intersensory integration studies - verbal, nonverbal material

Another approach to the memory and related abilities of RD children has been to investigate their performances in making associations between visual and auditory stimuli, tasks believed to mimic the complex reading process of associating printed letters and letter combinations with their phonemic counterparts. The usual format of such studies is to present paired stimuli, one visual and one auditory, and test subjects on their ability to match them together immediately or recognize or recall one or both after a delay. Both verbal and nonverbal material has been studied in order to make comparisons along this dimension, although some researchers contend that all nonverbal memory tasks are actually tests of verbal intermodal integration, as the memory process requires initial recoding into verbal form (Torgeson, 1979). Generally, RD children appear to be quite adept at visual recognition of letters and words, but have difficulty when required to name or otherwise re-code the visual input.

The earliest work using this paradigm is usually attributed to Birch and Belmont (1964, 1965). They first studied the abilities of normal children, aged 5 - 12, on an intersensory auditory-visual

integration task thought to represent the auditory-visual matching requirements of the reading process. Subjects were asked to match rhythmic tone patterns (auditory-temporal information) with their appropriate dot counterparts (visual-spatial information). The evidence from normals indicated that ability on this task improves with age, with the period of most rapid development between the ages of 5 and 7. Correlations between the intersensory task performance and reading skills were high in younger subjects; this effect was not as robust with older subjects. Birch and Belmont have speculated that intersensory integration is a necessary basic requirement for early acquisition of reading skills, but is not as necessary for continued gains in reading ability. Another interesting finding was the lack of correlation at all ages between intersensory task performance and auditory-verbal memory, as measured by the WISC Digit Span subtest score. This is consistent with the limitations of the Digit Span subtest as a measure of auditory-verbal memory discussed previously.

This same research team conducted a further study comparing RD children and age-matched controls on this task. As predicted, RD subjects performed more poorly than normals. An interesting corollary finding was that performance on the integration task differentiated varying degrees of reading skill in both groups, suggesting that visual-auditory integration skill is a continuous

predictor of reading skill. (This may also be interpreted as evidence that RD children, like normals, are heterogenous in nature and should be studied as distinct subtypes -- Doebling, et al., 1979; Rourke, 1983). As some overlap in integration task scores was found between groups, the authors are cautious to point out that intersensory integration is not "the sole factor underlying reading in competence" (1964, p. 861). Unfortunately, other factors, such as poorer perception and discrimination of rhythmic patterns in RD children, were not taken into consideration in the interpretation of these results.

Extending beyond simple inter-sensory matching skills to intersensory memory abilities, Swanson (1978) tested RD and normal children on their ability to recognize pictures of nonsense shapes; the two groups performed equally well on this task. However, in a second task in which the shapes were paired with arbitrary names, normals' recognition scores showed considerable improvement while RD children's performances remained unchanged. The author suggests that this lends further support to the notion that RD children are specifically impaired in the area of visual-verbal (naming, symbolic) integration. Similarly, Rudel et al. (1976) found RD children to perform more poorly than normals on a range of intra- and intersensory verbal integration tasks. Tasks included learning names paired with tactile Braille letters (auditory-tactile), names paired with the visual Braille dot

patterns (auditory-visual), and names paired with auditory Morse code tones (auditory-auditory). These researchers suggest that the RD memory impairment is a function of a generalized encoding and retrieval deficit for all verbal information. They contend that the "painful slowness of dyslexics' reading" is an indication of "the lack of automatized response to letter configurations" (p. 69), similar to the verbal memory deficits shown in the present results.

To study the inter-sensory, as well as intra-sensory skills of RD and normal children in greater detail, Zigmond (1966) tested all combinations of visual-auditory intra- and inter-sensory integration and found the auditory-auditory and visual-auditory tasks to be most problematic for RD children. However, Steger, Vellutino, and Meshoulam (1972) point out that these results may have been confounded by the unequal difficulty levels of the tasks used. Different tasks have been found to result in auditory-auditory and visual-visual intra-modal task deficits in RD children (VandeVoort, et al., 1972).

More basic issues of intra- and inter-sensory integration memory have been studied by focusing strictly on nonverbal tasks. Vellutino, Steger, and their associates have purposely avoided using linguistic stimuli as they view such material as contaminated, due to the negative stigma attached to them by

frustrated RD children. Pairing nonverbal visual "symbols" with each other and with tactile stimuli (textured materials), intra- and inter-sensory integration memory was tested through a forced choice recognition format (Steger, et al., 1972). As predicted, RD children performed similarly to normals on the intra-sensory tasks; contrary to other research findings, RD children had no difficulty on the inter-sensory tasks. Steger et al. offer the possibility that the inter-sensory integration problems faced by RD children are unique to the visual-auditory transfer, whether the material involved is verbal or nonverbal.

Further work into the visual-auditory transfer reveals that, using nonverbal auditory stimuli such as a hum, cough, or whistle, and pairing these with nonverbal visual designs, no differences between groups obtain (Vellutino, Steger & Pruzek, 1973). Similarly, no differences could be found on nonverbal visual half-field integration tasks tapping interhemispheric transfer skills and cerebral dominance (Vellutino, et al., 1978).

Rather, it appears that the auditory-visual cross-modal difficulties are unique to verbal material, the area of presenting weakness in RD children (Vellutino, et al., 1975). RD difficulties with these tasks have been attributed to a "basic distinction in the labeling process" (1975, p. 15), a notion held by many in the literature (Ellis, 1981; MacKinnon & McCarthy, 1973; Torgeson,

1985). This is further indicated by the pattern of errors which RD children exhibit on verbal auditory-visual CVC integration tasks; while normal children are prone to substitute phonetically-similar syllables, RD children insert 'real' syllables (Vellutino, et al., 1975). This perhaps relates to differences in phonetic skill suggested by other research in the verbal realm (e.g., Shankweiler & Liberman, 1979), forcing RD children to revert to their store of meaningful semantic information.

Vellutino and his colleagues present a somewhat different approach to these issues in their use of 'real life' linguistic stimuli (Vellutino, et al., 1973; Vellutino, Steger, Kaman & DeSetto, 1975). They used short Hebrew words as auditory stimuli and tested children's abilities to learn their graphic (visual) equivalents in RD, naïve normal, and normal children trained to read, speak, and write Hebrew. RD children performed in a fashion equivalent to the inexperienced normals; both groups performed significantly worse than the trained group. In addition, the naïve normals produced the same type (orientation) and frequency of errors as RD children, taken as evidence that common letter reversals in RD children are not visually-based. Rather, they contend that common letter reversals (e.g., b/d, p/g) are due to verbal intrusion errors. Nonetheless, this does not account for the common whole-word reversals seen in RDs (e.g., saw/was, from/form).

Likewise, using the visual equivalents of the Hebrew words just described, this same group of researchers tested RD, naive normal, and trained normal children in their abilities to make visual symbolic-graphic associations (Vellutino, Steger, DeSetto & Phillips, 1975). RD and untrained normals performed similarly at conditions of immediate and delayed (24-hour) recall. Noteworthy is the finding that these groups performed in a similar fashion to the trained normals at a 6-month delay period. Similarly, another study suggests that, although RD children require more trials to learn a nonverbal visual (geometric form) - verbal visual (CVC trigram) paired associate task to criterion, no differences are observed between RD and normal groups after a 24-hour delay (Otto, 1961). Practically speaking, this would appear to suggest that, given optimal conditions for learning (e.g., longer exposure times, more practice), RD children can equal their normal counterparts on certain memory task performances.

Gascon and Goodglass (1970) present another approach to the inter-sensory integration deficits issue in their study of the role which "informational content" (meaningfulness) plays in learning auditory-visual associations. They utilized two levels each of auditory and visual stimuli: those of 'low' and 'high' informational content. RD children were found to be poor at learning auditory-visual associations, particularly when both members of a pair were low in informational content. In contrast, RD children

performed much better with stimuli rich in informational content (e.g., auditory syllables resembling words, three-dimensional visual stimuli). Also, the difference between high and low-information task performances was much greater for RD than for normal subjects, suggesting that disabled children rely more heavily on informational content to make meaningful, memorable associations.

Another inter-sensory integration study varied modality, meaningfulness, and symbolic value (verbal/nonverbal) of stimuli (McGrady & Olson, 1970). "Social" stimuli consisted of words, common environmental sounds, and pictures of common objects, while "nonsocial" stimuli consisted of novel patterns, designs, and nonsense syllables. Only same/difference judgments were required of auditory/visual pairs. As in other studies, performance was significantly poorer for LD (RD and other academic disabilities) children on verbal pairs, regardless of modality or meaningfulness. The results are interpreted as indicative of slower decision or 'thought processes' in LD children. Perhaps, as suggested by other studies, these ill-defined 'thought processes' are related to deficits in the verbal recoding stage. Clearly, the heterogenous composition of the particular LD group studied warrants that only limited generalizations be made from these results.

Relating to the important issue of subtypes of reading disability, several groups of researchers have used the inter-sensory integration paradigms to test for intra-group differences. Cohen and Netley (1978), for example, tested two groups of reading and spelling-disabled children and a group of normal readers on a battery of visual-verbal paired associate and visual-nonverbal recognition tasks. The two RD group were distinguished on the basis of WISC VIQ-PIQ splits: One group was defined by obtaining approximately equivalent Verbal and Performance IQ scores, the other by VIQ scores 15 or more points lower than PIQ scores (suggesting greater language-related deficits). The largest differences between the RD and normal groups were found on visual-verbal tasks. As well, although RD children performed adequately on simple letter and word-recognition tasks, supraspan serial position curves showed significantly poorer RD recall over all positions of simple recall. These results were interpreted as indications of a lack of flexibility in RDs' memory systems, breaking down significantly on supraspan tasks, perhaps as a result of "information overload" and a failure to rehearse adequately. An interesting finding in this study, addressed briefly by the authors, was that the two RD groups performed differently on some of the memory tasks. The low VIQ group performed significantly worse on tasks assessing semantic processing of auditory-verbal material. In light of the wealth of data suggesting that clear-cut and reliable RD subtypes

exist, this finding certainly merits further research.

More recently, subgroups of RD children were tested on nonverbal auditory-visual integration tasks by Bauserman and Obrzut (1981). Tasks consisted of a flashing light (visual-temporal condition), beep patterns (auditory-temporal condition), and printed dot patterns (visual-spatial condition); these were paired in various combinations to test both intra- and inter-sensory spatial and temporal skills. These researchers hypothesized that a crucial element underlying RD performances may be whether stimuli are presented in sequential (temporal) or simultaneous (spatial) fashion, in accordance with cerebral asymmetry studies which posit that these represent the functions of the two cerebral hemispheres (sequential = left, simultaneous = right). RD subjects were grouped according to Boder's (1973) classifications: dyseidetic (difficulty with preserving the visual 'gestalts' of words), dysphonetic (difficulty with preserving the phonetic aspects of words), and alexics (a more serious disorder involving difficulties with both the visual and phonetic aspects of words). As other studies have demonstrated, RD children performed quite well on 'pure' spatial (spatial-spatial matching) tasks, but had difficulty on tests assessing temporal-spatial (intra and inter-sensory) and temporal-temporal (visual-auditory) matching skills. In accordance with their subtype classification scheme, the alexic group evidenced the lowest scores on these

tasks, dyseidetics the highest, and the dysphonetics fell in-between. Low scores on the intersensory integration are noteworthy, as this task is thought to represent the auditory-visual transfer process involved in reading.

A similar trend in performances between these three groups was demonstrated by Obrzut (1979) using dichotic listening and auditory-visual digit tasks. Dysphonetic and alexic children performed poorly on both auditory and visual tasks while dyseidetics performed in a manner similar to controls.

In contrast to some researchers' notions that these classifications represent merely points along a continuum of reading skill (e.g., Jorm, 1979), the alexics in Bauserman and Obrzut's study showed a qualitatively different pattern of performance: They performed better when presented with spatial stimuli and when asked to match them to temporal equivalents than when presented with the reverse task. Dyseidetics and dysphonetics performed in an opposite fashion on these two tasks. The authors conclude that the various patterns of performance indicate mild impairments of sequential processing in dysphonetics and, to a greater degree, in alexics, implicating left hemisphere dysfunction. They also propose that the dyseidetic pattern of primary difficulty with simultaneous-spatial processing may implicate right hemisphere dysfunction.

g. Memory skills and mnemonic training

Specific memory training in the use of rehearsal (Hicks, 1980; Torgeson, 1977), mnemonic chunking (Torgeson & Goldman, 1977; Torgeson & Houck, 1980), and other conceptual grouping techniques (Dallago & Moely, 1980; Torgeson, Murphy & Ivey, 1979) has been shown to improve RD children's memory test performances to a level more commensurate with their normal age-mates. Such research indicates that mnemonic strategies or memory "control processes", rather than fixed functions as such, may be the major variable distinguishing RD and normal children. On the hopeful side, such deficiencies would be directly amenable to remediation. However, the particular studies cited simplify the issue somewhat, as only easily-grouped or rehearsed stimuli were employed in their designs. Given real-life examples of material that needs to be memorized (e.g., definitions or spellings of words, names and dates in a lesson), these forms of mnemonic training alone may well not improve RD performances to a level equivalent to normals. Nonetheless, classroom research on specific visual-verbal mnemonic strategies is currently underway and suggests promising results (Pressley et al., 1987).

To summarize briefly, the general findings from the RD-memory research appear to be that significant differences do obtain when comparing RD and normal children on their performances of specific, controlled tasks. As the preponderance

of auditorially-presented information is verbal in nature, the majority of research indicates that this is a poor modality for RD children on memory tasks. Specifically, it appears that auditory-sequential and verbatim recall are the areas of primary deficit. Along these lines, it appears to be the inadequacy of the internalized phonetic code which contributes to RD deficits in rote auditory-verbal recall, as these children often lack an efficient system for encoding and decoding incoming verbal stimuli. In addition, verbal-linguistic information presented through the visual modality has generally been found to pose difficulty for RD children on recall and recognition tasks. This specific impairment, which is most pronounced for unfamiliar, less-easily named stimuli, appears to be a reflection of a weakness in the intermediary naming or phonetic-recoding stage necessary for the processing of any verbal-type material. A consistent and positive finding is that memory for meaning, regardless of modality of presentation or type of material, is quite well-developed in RD children.

Visual memory for nonverbal material such as pictures, designs, and abstract figures appears to be free of deficit in RD children on tasks not requiring, or facilitated by, naming strategies. Similarly, the majority of studies investigating inter-modal association skills suggest that RD children's difficulties are largely confined to the visual-auditory transfer of

information. On a neurological level, this evidence is consistent with Geschwind's (1965, cited in McKeever & VanDeventer, 1975) notion that dyslexia involves maldevelopment of both angular gyri, which function as an inter-modal 'translating device'.

The different focus taken by those favouring the 'control process' approach adds another important dimension for investigating and understanding memory skills and designing remedial programs for RD children. Although some improvements have been brought about through isolated instances of mnemonic training, it remains to be tested how far these results may be generalized. The research investigating specific reading disability subtypes also suggests that different degrees of processing inefficiencies may exist, each requiring its own intervention strategies.

D. Arithmetic Disabilities and Memory Functions

The role which memory functions play in the acquisition and development of arithmetic skills, while seemingly quite separate from those involved in the reading process, is substantial.

These functions range from the need to memorize specific facts verbatim ('static memory') to a variable recollection of the many steps involved in any one procedure ('dynamic memory'). Among the subskills required to plan and carry out a multiplication

problem, for example, are "... static memory for the appropriate tables involved... a dynamic memory for operations which involve the carrying of numbers [and a] final addition employing dynamic memory for carrying of numbers to achieve a solution to the problem." (Cohn, 1961, as discussed in Webster, 1979). Furthermore, Siegel and Linder (1984) have discussed the roles of the articulatory loop and executive systems of memory proposed by Baddeley: The former is believed to be involved in superficial aspects of arithmetic procedures (e.g., identifying mathematical signs) and numerals), while the latter is believed to be involved in retrieving the algorithm needed to perform the called-for operation. The importance of the relationship between arithmetic skill and memory ability is suggested by Tuokko (1982) who found a strong correspondence between verbal memory problems and arithmetic difficulties. However, despite the obvious cognitive links, little research has examined specifically the memory functions of arithmetic-disabled youngsters.


In the clinical study of arithmetic subtypes, Siegel and Feldman (1983) have demonstrated that AD children display a greater propensity towards visual-verbal memory difficulties than a clinical comparison sample. Other research on a clinically-inferred academic subtype, showing relative deficits in mechanical arithmetic suggests approximately average scores on tests of immediate sequential memory (Digit Span), while

short-term auditory-verbal memory for meaningful information is below-average (Benton's Sentence Memory Test - Rourke & Finlayson, 1978). On both tasks, however, the AD group studied performed significantly better than children with relatively poor reading and those with general academic impairments. The finding of below-average Sentence Memory performance is noteworthy, as it may be related to below-average scores on other specific auditory-verbal processing tasks (Strang & Rourke, 1985). All of these tasks (Sentence Memory, Auditory Closure, Verbal Fluency) appear to share the characteristic of task novelty, a specific quality which appears to pose difficulty for AD children. Furthermore, follow-up study of these AD individuals in adulthood suggests that the learning of novel stimuli and adaptation to novel situations remains problematic throughout life (Rourke, Young, Strang & Russell, 1985).

More specific research on arithmetic-disabled (AD) children reveals that significant differences obtain when comparing normal-achieving and severely mathematically-disabled children on verbal short-term memory tasks (Webster, 1979). However, it is important to note that no differences could be found between a mildly-impaired math group and normals. Disabled students performed relatively better in the visual mode while non-disabled students were superior in the aural mode. An important consideration here is that no mention is made of these subjects'

reading abilities; therefore, Webster's subjects may not be directly comparable to a more proficient reading and spelling AD subtype, such as the group isolated by Rourke and Finlayson (1978).

This evidence for somewhat better visual than auditory-modality memory skills in an AD group is contradicted by the results of a study conducted by Siegel and Linder (1984). Using stringent group selection criteria, these researchers compared groups of reading-disabled (who often exhibited arithmetic disabilities as well), arithmetic-disabled (non-reading disabled), and normally-achieving youngsters on visually- and auditorially-presented verbal memory tasks. Included in the lists were phonetically-confusable items to explore further the relationships between phonemic coding processes, short term memory skills in general, and various types of learning disability. Results showed that both RD and AD groups were insensitive to the effects of phonetic confusability at younger ages (an unexpected finding, in light of research suggesting average rote auditory-verbal skills in Rourke and Finlayson's Group 3, AD subtype). However, while reading-disabled children were poor on both auditory- and visual-memory conditions, arithmetic-disabled children were only deficient in the visual condition. While giving short shrift to this latter finding, Siegel and Linder conclude more generally, "short term memory abilities are related to functions other than learning to read. Short-term memory may have a



significant role in a variety of cognitive functions of which reading is only one." (1984, p. 206) The AD-group impairment on a visually-presented task suggests some similarity to Strang and Rourke's (1985a) extensive discussion of the visual-organizational impairments shown by AD children.

Another study using similar, well-defined subtypes suggests a between-groups dissociation of auditory-verbal and visual-nonverbal memory skills (Fletcher, 1985b). As predicted, RD (and spelling-disabled) children performed poorly when learning lists of words through a selective reminding technique, while they performed in a manner similar to normals in learning nonverbal dot matrix patterns. AD children performed in an opposite fashion on both tasks. Furthermore, the pattern of academic achievement appears to affect group performance in a manner compatible with other neuropsychological test findings. Children uniformly deficient in reading, spelling, and arithmetic performed poorly on both verbal and nonverbal memory tasks. Another group, not previously studied, who were deficient in spelling and arithmetic only resembled the AD (only) group. In a general discussion of LD subtyping research, Fletcher (1985a) also discusses the important research potential of such studies in providing external validation of already-derived LD subtypes.

E. Rationale for Study

As alluded to earlier, in addition to studying the memory processes and differences of various subtypes of learning disability, the objective of providing external validation of already-existing subtypes underlies the sort of research undertaken here. As Fletcher (1985a,b) has discussed, external validation allows one to understand better the importance of subtype differences and aids in the determination of reliable typologies to which new members can be assigned. Should clear-cut between-group differences obtain on measures not used in the original subtyping analysis, one can infer with greater confidence that these skill groups represent actual unique clinical populations. In turn, remediation techniques can be designed and applied with greater precision for each group, based on each group's cognitive and behavioural needs. Examples of this type of remediation technique, based on clinical-statistical findings, is presented in Strang and Rourke (1985a) in relation to a neuropsychological subtype deficient in socioemotional coping skills.

In addition to the possibility for remedial program development, the present social context of this study offers further timely justification. Bill 82, the recent amendment to the 1974 Ontario Education Act introduced in the Provincial Legislature, specified the following in regard to LD children:

The Minister [of Education] shall ensure that all exceptional children in Ontario have available to them, in accordance with this Act and the regulations, appropriate special education programs and special education services without payment of fees by parents or guardian residents in Ontario the Minister shall require school boards to implement procedures for early and ongoing identification of the learning abilities and needs of students

(Reference Note 1)

The provisions of Bill-82 have since been enacted and the impact of the Bill proves to be profound, in rapidly accommodating disabled students in specialized elementary and secondary-school learning settings. Consequently, the need for LD identification criteria and the development of remediation programs has never been higher in the Province. As well, given the fact that "graduates" of Bill-82 are starting to make their way into the Province's universities and colleges, the importance of testing and remediation methods and programs cannot be overstated: The very basis of teaching and learning processes, with respect to all students in the Province, and at all curricular levels, are under intense scrutiny as they have never been before.

E. Rationale and Statement of Specific Hypotheses

The following hypotheses are presented in accordance with the current body of LD-memory research. Comparisons for the present

study were made between normals (Group C) and two groups of age-matched LD youngsters: one exhibiting significant deficiencies in reading (Group RD), another exhibiting significant deficiencies in mechanical arithmetic (Group AD). A more precise description of these groups and the specific memory tasks employed is provided in the Methods section.

1. Rationale for Hypothesis 1

Generally, it has been demonstrated through the various studies examining RD and AD children's performances on memory tasks that both of these disabled groups are deficient in their short-term memory skills. However, very few studies have made direct comparisons between these two LD groups and normals (Fletcher, 1985a; Rourke & Finlayson, 1978; Siegel & Linder, 1984). Thus, it would be fruitful to compare these groups on a wider range of memory tasks to explore their general mnestic abilities relative to each other and to normal controls.

Hypothesis 1:

Groups RD and AD will perform in a fashion inferior to Group C using a composite index of 'memory ability' obtained through a battery of memory tasks designed to assess various aspects of short-term mnestic functions.

2. Rationale for Hypothesis 2

Many LD studies have indicated auditory-verbal and psycholinguistic deficits in RD children (e.g., Doebling, 1985; Doebling, et al., 1979; Rourke, 1978; Rourke & Finlayson, 1978). On the other hand, visual-perceptual skills and nonverbal processing of information appear to be areas of primary weakness in children with relative weaknesses in mechanical arithmetic (e.g., Rourke & Strang, 1978). Therefore, it would appear likely that specific memory tasks designed to assess skills within the verbal and nonverbal realms would also reflect this dissociation between the two LD groups. One memory study to date has already demonstrated such a relationship (Fletcher, 1985b).

Many of the RD memory studies addressed in the review of the research discussed earlier have implicated the independence of verbal and nonverbal short-term memory processes. Further evidence relevant to this issue is suggested by neurological studies. The latter have shown specific verbal memory deficits following left hemisphere lesions and specific nonverbal memory deficits following right hemisphere lesions (Kimura, 1963; Milner & Taylor, 1972; Warrington & Shallice, 1969).

Furthermore, modality of memory task presentation appears to produce performance differences in LD groups. While RD children perform poorly on verbal tasks, regardless of modality (auditory or

visual), AD children appear to have particular difficulty with verbal and nonverbal memory tasks presented in the visual modality (Siegel & Linder, 1984). This latter finding appears to relate to the more general AD impairment in visual-spatial processing of information (Strang & Rourke, 1985a).

Hypothesis 2 (a):

Group RD will perform in an inferior manner to Group C on a verbal-oriented (words as stimuli) memory task while performing in a similar fashion to Group C on a nonverbal (design as stimulus) memory task. In addition, Group AD will perform as well as Group C on a verbal memory task while performing in a fashion inferior to both Groups RD and C on a nonverbal memory task.

Hypothesis 2 (b):

Considering only the modality of presentation of the verbal memory tasks, it is expected that Group RD will perform in a manner inferior to Group C with both visual and auditory presentations. Group AD will perform as well as Group C on verbal tasks in the auditory modality, yet in an inferior manner with verbal tasks in the visual modality.

3. Rationale for Hypothesis 3

Considering only the nonverbal tasks, the quality of nonverbal memory task performance is expected to differ between groups.

The nonverbal memory task chosen for the present study (Rey Osterrieth Complex Figure) allows for discrete comparisons of memory for configurational elements and internal details. Recently-developed scoring methods also provide for comparisons of general organization and style (Waber & Holmes, 1985; 1986). Relatively good inter-method reliability is reported between clinical ratings and the objective quantitative scoring procedure employed in the present study ($r = .77$, $p < .0001$; Waber & Holmes, 1986).

The literature on visual-spatial copying skills in groups of brain-damaged adults (Binder, 1981; Gianotti & Tiacchi, 1970; Haecan & Assan, 1970; Reitan, 1979), as well as clinical descriptions of LD children (Rourke, et al., 1983), suggest that difficulties in left-hemisphere verbal abilities (as seen in RD children) are associated with deficiencies in preserving internal elements and verbally-encoded details, while difficulties in nonverbal processing subserved by the right hemisphere (as seen in many AD children) are associated with failure to preserve the overall 'gestalt' of visual-spatial configurations. Nonetheless, it appears that little direct evidence exists to suggest what happens in these patterns of visual-spatial organization over time; i.e., does a long-term memory requirement further exacerbate the tendency to delete details or gestalt features? Thus, it would be interesting to examine these skills in homogenous groups of LD

children, investigating and comparing both immediate copying and long-term nonverbal recall.

Hypothesis 3:

Group AD will perform in an overall manner inferior to Groups RD and C in the accuracy of both copy and memory phases of the nonverbal tasks. It is further expected that Group AD will obtain poorer organizational scores in the memory phase and that memory for specific features will deteriorate more rapidly (i.e., greater drops in scores from copy to recall). In terms of qualitative feature scores, Group AD is expected to obtain lower scores than the other groups on outer detail ('gestalt') organizational features while Group RD will show a tendency toward lower scores on internal detail features.

4. Rationale for Hypothesis 4

The phonological-encoding deficit hypothesis, explored in relation to RD- short-term memory performance has gained consistent support under conditions of both auditory and visual presentation of stimuli (e.g., Liberman et al., 1982; Mark et al., 1977). The only study to date examining the phonological-encoding abilities of AD children suggests impairment in younger members of this group as well (Siegel & Linder, 1984). This latter finding is rather contradictory to other neuropsychological research suggesting well-developed rote phonological processing in AD

children (e.g., Rourke & Finlayson, 1978), although the difference in subjects' ages between studies may account for some of this discrepancy. Therefore, to clarify this issue, it is well to study older subjects from each of these disability groups and normals in relation to their abilities to attend to the phonological characteristics of verbal stimuli on memory tasks. Both visual and auditory modalities were studied for comparison purposes.

Another dimension of phonological encoding skill relevant to verbal memory performance relates to already-established phonological codes. Specific impairment of these abilities has been reported for RD children (Ridgely, 1970), although no comparisons appear to be available for AD children. The evidence from other LD neuropsychological studies would suggest that this rote auditory-verbal skill is intact for AD children.

Hypothesis 4(a):

Group RD will be less affected by phonologically-confusable foils in a short-term verbal memory recognition task, in comparison to Groups AD and C. This will result in a lower proportion of phonetically-similar errors, although their total number of errors may equal or exceed significantly that of Groups AD and C. This effect is expected to obtain under conditions of auditory and visual presentation.

Hypothesis 4(b):

Group RD will perform in an impaired fashion, relative to Groups AD and C on a rhyme-production task designed to assess already-established phonological codes.

6. Rationale for Hypothesis 5

A final variable of interest, suggested by other memory research, relates to the recognition or recall format of the task. While it appears that no direct comparisons between recall and recognition format have been made in a single LD-memory study, the format of memory task response would appear to be a useful dimension to investigate, given the nature of academic tasks more generally. Along these lines, one aspect of certain forms of learning disability is the tendency for a child to have difficulty with the production of responses, as in the case of a child with specific oral or written expressive deficits. In addition, the production of responses may be an area of difficulty for other LD children due to the psychological 'trauma' of repeated failure following their academic responses in class. While a production or expressive deficiency in the groups of LD children would be expected to disrupt their recall performance, it should not impair recognition (where only matching of response is required). Furthermore, this within-groups comparison allows one to test the notion that recognition tests are generally more sensitive measures of 'mnestic function' than are recall tests (Zechmeister

& Nyberg, 1982)

Hypothesis 5:

All three groups will perform better with recognition than with recall response format of the various verbal tasks. Between-groups comparisons will reflect superior recall task performances in Group C than in disabled Groups RD and AD.

Chapter II

METHOD

A. Subjects

Thirty-two LD children with specific patterns of academic performance were selected from the files of psychological services in a large metropolitan parochial school board in Ontario. All of these children had been identified as 'hard to serve' (Reference Note 2) by the school board. Specifically, it was decided that each child met the criteria for Specific Learning Disability (see Appendix B for the Ontario Ministry of Education definition of learning disability) through the Identification, Placement, and Review Committee meeting of school board personnel. All children were enrolled, on a full- or part-time basis, in Specific Learning Disability classrooms.

To insure that all children were of normal intelligence, a prerequisite for the definition of specific learning disability accepted here (Rourke, 1975), only children falling within one standard deviation of the mean on Wechsler IQ tests (1949, 1974) were selected (i.e., children falling within Full Scale IQ range 86 - 114). Thirty-eight normal children were selected from regular classrooms in the same lower middle and middle-class schools in this metropolitan school district to control for social class and other potentially confounding variables specific to the individual

school. In order to equate the LD and normal groups for age (range 10 - 14 years) and Full Scale IQ, 16 subjects were excluded from the total group, resulting in a total sample size of 54 subjects. This exclusion was decided upon in favor of a post hoc analysis of covariance procedure, which can confound and lower covariate effects' (Adams, et al., 1985). The following exclusion and selection criteria were utilized:

(1) In accordance with the commonly-accepted definition of learning disability (Rourke, 1975), all children were judged to be free of the following deficits -

- a. Primary sensory disturbances
- b. Emotional disturbances (defined as referral to a mental health professional or treatment centre)
- c. Sensory, cultural, emotional, or educational deprivation

As ethnic backgrounds varied in the overall classroom group, only children who had attended all years of schooling in English and whose families spoke English at home were selected.

Information obtained from other testing procedures (e.g., vision and hearing screenings), parent, school, and social-service reports were used to establish that the above criteria had been met. If such information was not obtainable for a particular child, that child was not considered as a possible subject.

(2) In accordance with other LD literature (e.g., Fletcher, 1985b) the following criteria were used to define Group RD -

- a. Wide Range Achievement Test (Jastak & Jastak, 1978) centile score on the Reading subtest did not exceed the 31st centile
- b. WRAT Arithmetic centile score above 30 and at least one-half standard deviation above the Reading subtest

(3) The following criteria were used to define Group AD -

- a. WRAT Arithmetic subtest centile score did not exceed the 31st centile
- b. WRAT Reading subtest centile score above 39 and at least one-half standard deviation above the Arithmetic subtest

As is apparent from the above definitions, the LD groups were selected on the basis of greatest area of academic weakness, as it is quite difficult to find groups deficient in only one academic area.

(4) The following criteria were used to define Group C -

- a. WRAT Reading, Spelling and Arithmetic subtest centile scores above 39th centile
- b. No evidence of learning difficulty, according to teacher report

Descriptive characteristics of the three achievement groups are presented in Tables 1 and 2. Chi square analyses performed on the Sex ($\chi^2 = 1.53$, $p = .47$) and Handedness ($\chi^2 = 1.36$, $p = .61$) variables did not reveal any between-group differences. One-way analysis of variance tests for Age ($F(2,51) = .80$, $p = .46$) and for WISC-R FSIQ ($F(2,51) = 1.70$, $p = .19$) revealed no between-group differences. Rough estimates of Verbal and Performance IQ are also presented in Table 2. As these 'Verbal' and 'Performance' indices were derived from only two of the five WISC-R subtests in each category, adequate between-groups ANOVAs could not be calculated. Nonetheless, ANOVAs computed for each of the individual WISC-R subtests administered (Information, Vocabulary, Picture Arrangement, Block Design) revealed no significant differences on the Information or Picture Arrangement subtests. The Block Design ($F(2,49) = 4.16$, $p < .05$) and Vocabulary subtest score ($F(2,49) = 4.96$, $p < .05$) comparisons yielded significant between-group differences. Post hoc Neuman-Keuls Tests resulted in predictable findings: The AD group performed significantly worse than the other groups on the nonverbal Block Design subtest while the RD group performed significantly worse than the other groups on the verbal Vocabulary subtest.

Statistically significant between-groups differences obtained for the WRAT scholastic measures. Post hoc Neuman-Keuls Tests revealed that the statistically significant between-groups

Table 1 - Descriptive characteristics of learning-disabled and non-disabled subjects by group classification

<u>Group</u>	<u>RD</u>	<u>AD</u>	<u>C</u>	<u>Total</u>
N	11	12	31	54
Males	10	10	23	43
Females	1	2	8	11
Right hand dominant	10	9	27	46
Left hand dominant	1	3	4	8

Table 2 - Means (standard deviations) for Age, WISC-R FSIQ, WRAT subtest grade-equivalent scores and percentiles by group membership

	<u>GROUP</u>			
	<u>RD</u>	<u>AD</u>	<u>C</u>	<u>TOTAL</u>
AGE(in mos.)	141.73 (9.99)	147.50 (13.23)	147.35 (14.20)	146.24 (13.21)
FSIQ	98.09 (9.18)	97.92 (7.63)	101.84 (8.15)	100.20 (8.67)
VERBAL IQ INDEX	82.41	92.54	96.61	92.91
PERFORMANCE IQ INDEX	112.73	100.00	109.19	107.87
WRAT READING GRADE-EQUIVALENT*	4.57 (.91)	7.49 (1.51)	8.01 (1.12)	7.19 (1.78)
WRAT READING PERCENTILE*	19.91 (7.89)	64.88 (21.54)	75.68 (13.15)	61.91 (26.17)
WRAT ARITHMETIC GRADE-EQUIVALENT**	5.88 (.81)	4.12 (.75)	6.81 (1.14)	6.02 (1.47)
WRAT ARITHMETIC PERCENTILE**	40.64 (7.86)	9.17 (6.71)	53.87 (13.94)	41.24 (21.38)

* $p < .0005$ RD < AD, C

** $p < .0005$ AD < RD < C

differences for WRAT Reading grade-equivalent scores ($E(2,51) = 34.76, p < .0005$) and WRAT Reading percentiles ($E(2,51) = 59.30, p < .0005$) clearly distinguished the RD from both AD and C groups (with the RD group obtaining poorer Reading scores). Furthermore, the post hoc Neuman-Keuls Tests performed on the statistically significant ANOVAs for WRAT Arithmetic grade-equivalent scores ($E(2,51) = 30.98, p < .0005$) and WRAT Arithmetic percentiles ($E(2,51) = 63.53, p < .0005$) revealed that the AD group performed in an inferior manner to both RD and C groups and that the RD group performed in an inferior manner to the C group (suggesting mild arithmetic problems in addition to significant reading disability, similar to the disability profile reported by other researchers).

B. Materials

Verbal and nonverbal testing materials were constructed in the following manner (word lists and nonverbal stimuli are provided in Appendix B):

(1) Verbal lists

High frequency (occurring at least 50 times per million words of general text and high frequency in juvenile texts) one-syllable words from the Thorndike-Lorge (1944) word list comprised the verbal conditions. Only 4- and 5-letter words were chosen. These words had been pre-tested on a group of young LD/emotionally-disturbed children and were found to be highly

pronounceable and readable.

In order to approximate a verbal corollary of the nonverbal task chosen for study (Rey Osterrieth Complex Figure), an incidental verbal memory task was designed (Condition A), including copy and recall phases. For the recognition-format conditions (Conditions D & E), each probe word was combined with two other distractors. The three words were randomly varied in presentation. One distractor-word was a phonetically-similar (rhyming) word of the same length, while the other distractor was a phonetically-dissimilar word of the same length. All words were selected from the Thorndike-Lorge high frequency ratings and were deemed to be well within the reading level (approximately grade 1 - 2) and pronounceability of children of age 10 - 14.

These verbal lists were presented in two modalities, auditory and visual. Auditory lists were read by the examiner at the approximate rate of one item per two seconds. The first visual list (Condition A), which was to be copied by the children, was presented simultaneously on one page, printed in lettra-set letters. All other visual lists were printed in lettra-set letters on 3" x 5" index cards and presented at the rate of one item per two seconds. Each visual and auditory list was comprised of 10 items.

(2) Phonological task

A modified version of the Rhyme Word-Fluency Task, as used by Ridgely (1970), was administered as the measure of long-term phonological memory skill. Subjects were requested to respond orally with as many words as they could which rhymed with four simple stimulus words (go, tree, car, write). Maximum was 10 responses in a 45-second time limit.

(3) Nonverbal material

The design stimulus for the nonverbal conditions was the Rey-Osterrieth Complex Figure (Osterrieth, 1946). A reproduction of this figure, mounted on heavy cardboard, was presented horizontally to each child. Children were given a piece of white paper and five coloured pencils for the copy and recall phases of the task. Copy was completed with the stimulus figure in full view, while recall was assessed 20 minutes after initial presentation. The scoring of 'Gestalt' and 'Internal' features and Organizational quality was based on an adaptation of Waber and Holmes' (1985, 1986) procedure, illustrated in Appendix C.

C. Procedure

Subjects were administered the WRAT and the experimental memory measures individually in a quiet room. As the WISC-R had not been administered by an experienced school board clinician within one year of the testing date, four WISC-R subtests

(Information, Vocabulary, Picture Arrangement, and Block Design) were administered to each child and the scores pro-rated to obtain an estimate of FSIQ. This abbreviated version was selected in order to limit the duration of the testing session, thereby reducing the possibility of subject fatigue. Validity coefficients between the four-subtest pro-rated scores and Full Scale IQ scores based on ten subtests appear to be sufficiently high to permit such a substitution ($r = .911$, Sattler, 1982). The method described by Tellegen and Briggs (1967, cited in Sattler, 1982 -- Reference Note 3), which utilizes a constant derived from the intercorrelations of the four subtests yielding a Deviation Quotient estimate of Full Scale IQ, was used in this study.

Each verbal memory task (Visual, Auditory; Recall, Recognition) was preceded with the following instructions: "You are about to see (hear) a list of items. Please pay careful attention, as you will be asked to remember as many items as you can. The order in which you recall items is not important." For all verbal tasks, up to one minute was allowed for free recall and 10 seconds per item in recognition conditions. Specific instructions regarding the mode of recall/ recognition were given in advance of each task. Also, the presence and need for use of the tape recorder was explained prior to all instructions.

Tasks were presented in the following order:

(1) Verbal Condition A - visual presentation - copy phase

Children were shown the entire list of 10 words and were asked to print them on a piece of unlined paper. They were instructed to take their time and copy each word carefully until they felt that they had finished. No mention was made of the fact that recall would be tested later.

(2) Nonverbal design - visual presentation - copy phase

Subjects' papers were fastened to the table with tape to prevent rotations. In accordance with the method prescribed by Wáber and Holmes (1985), the children were shown the design and were given the first of five coloured pencils (the order of the pencils was pre-arranged). They were instructed to begin drawing the figure until the signal to switch pencils (after 45 seconds), at which time the task continued with a new pencil. This format continued until the children reached their last pencil. They were then instructed to continue their drawings until they felt they had finished. No mention was made of the fact that recall was to be tested later.

(3) Wide Range Achievement Test

The Reading and Arithmetic subtests of the WRAT were administered to the subjects according to standardized instructions.

(4) Verbal Condition A - recall phase (20 minute delay)

Children were given a piece of unlined paper and asked to write or print as much of the original list of 10 words. Sufficient time to complete this task (no more than 5 minutes was required) was allotted.

(5) Nonverbal design - recall phase (20 minutes)

In accordance with the "delay condition" method prescribed by Holmes and Waber (1986), the children were given a piece of unlined paper and were asked to draw as much of the original design as they could, using the coloured pencil of their choice. Sufficient time to complete this task (no more than 5 minutes was required) was allotted.

(6) Verbal Condition B - auditory presentation - recall format

Following presentation of the complete list of 10 items, the children were asked to recall (recite) as many words as they could. The children's responses to this and the other auditorally-presented list were tape-recorded to insure an accurate scoring of responses.

(7) Verbal Condition C - visual presentation - recall format

Following presentation of the complete list of 10 items, the children were asked to recall (write or print) as many words as possible. They were given 10 sheets of blank paper of the same

size as stimulus words on which to write or print their responses. Oral responses were noted and the children encouraged to write or print these responses, regardless of spelling.

(8) Verbal Condition D - auditory presentation - recognition format

Following presentation of the complete list of 10 items, the children were read the recognition stimuli, each consisting of three items. They were asked to select the word they remembered having heard.

(9) Verbal Condition E - visual presentation - recognition format

Following presentation of the complete list of 10 items, the children were shown the recognition stimuli, each consisting of three items. They were asked to point to the words they remembered having seen.

(10) Rhyme production task - auditory presentation - long-term recall format

The following instructions were read before each stimulus word: "You are to name as many words as you can which rhyme with the word you are about to hear. Remember to say as many words as you can before I say stop. The word is go (tree, car, write)." The child's oral responses were recorded by the examiner

in writing and with a tape recorder.

The order listed above alternates modality of presentation in an effort to reduce the amount retroactive and proactive interference, possible factors contributing to poor performance on memory tasks (Zechmeister & Nyberg, 1982). The first two tasks were followed by the WRAT in order to control for any interference caused by presentation of later memory items.

A one-page summary of results was compiled on each subject which served as test feedback for the child's parents.

D. Statistical Tests

In order to complete the following analyses, some of the scores were converted to standard I-scores ($M = 50$, $SD = 10$) based on the scores obtained by the normal control children (Group C). Similar T-score conversions have been performed in other LD-subtype studies (e.g., Rourke & Finlayson, 1978) based on the grand (i.e., total sample) mean and variance. It was decided in this study to base I-scores on the control group in an effort to make meaningful clinical contrasts with a non-disabled sample. These I-score conversions enabled direct inter-task comparisons involving different units of measurement (e.g., Rey-Osterrieth recall vs. verbal list recall) by converting the measures into standard units. Furthermore, this manipulation was intended to

control for varying levels of difficulty on the various tasks, a concern raised by other researchers exploring LD children's memory skills (Jorm, 1983). As well, graphic comparisons were facilitated using this technique.

(1) To test Hypothesis 1, the prediction that differences would obtain between groups in general 'memory ability', a multivariate multiple analysis of variance (MANOVA) was performed:

Independent variable = Subject group (RD, AD, C)

Dependent variables = T-scores on six measures of short term memory (derived from raw recall/recognition scores on Verbal Conditions A,B,C,D,E, and Rey-Osterrieth Figure per cent retained copy to recall phases)

(2) To test Hypothesis 2(a), the prediction that nature of test material would interact with subject group, such that Group RD children would perform poorly on Verbal tasks while Group AD children would perform poorly on Nonverbal tasks, the following two-way ANOVA was performed:

Independent variables = Test material (Verbal, Nonverbal) x Subject group (RD, AD, C)

Dependent variable = T-scores calculated for per cent recall on Rey-Osterrieth Figure and Verbal Condition A memory tasks

(3) To test Hypothesis 2(b), the prediction that modality of verbal task presentation would interact with subject group, such that Group RD children would perform poorly on Visual and Auditory Verbal tasks while Group AD children would perform somewhat poorly with Visual Verbal tasks only, the following two-way ANOVA was performed:

Independent variables = Modality of Verbal task presentation (Visual, Auditory) x Subject group (RD, AD, C)

Dependent variable = Combined raw scores on recall and recognition Verbal memory tasks

(4) To test Hypothesis 3, the predictions that (a) Group AD would perform more poorly than the other groups in Copy and Recall accuracy, (b) Group RD would perform poorly on recall of Internal detail features, while Group AD would perform poorly on recall of Gestalt features of the nonverbal design, and that (c) Group AD would obtain lower Organizational scores than the other groups, the following two-way and one-way ANOVAs were performed:

Independent variable = Subject group (RD, AD, C) x Phase of Task (Copy, Recall)

Dependent variables = Copy Accuracy scores, Recall Accuracy scores

Independent variable = Type of design feature (Internal Detail, External Gestalt) x Subject group (RD, AD, C)

Dependent variable = Both raw scores (converted to I-scores) and per cent of features retained from copy to recall phases of the Rey Osterrieth task (two separate ANOVAs were computed for comparison purposes).

Independent variable = Subject group (RD, AD, C)

Dependent variable = Rey Osterrieth Organizational scores

(5) To test Hypothesis 4(a), the prediction that Group RD would be less-affected by phonetically-confusable items, percentage of phonetically-confusable (rhyming) word errors on the verbal recognition tasks (both auditory and visual) were compared between groups through a one-way ANOVA:

Independent variable = Subject group (RD, AD, C)

Dependent variable = Percentage of phonetically-confusable errors (combined scores on Visual and Auditory recognition tasks)

(6) To test Hypothesis 4(b), the prediction that Group RD would not perform as well as the other groups on a long-term phonological memory task, raw scores from the Rhyme Word-Finding Test were analyzed through a simple one-way ANOVA:

Independent variable = Subject group (RD, AD, C)

Dependent variable = Raw scores on Rhyme Word Fluency Task
(4 trials summed)

(7) To test Hypothesis 5, the prediction that both groups of LD children would perform in a manner inferior to normals on recall tests, and that, within-groups, each would perform better with recognition than with recall memory tasks, the following two-way ANOVA was performed:

Independent variables = Format of test (Recall, Recognition) x Subject group (RD, AD, C)

Dependent variable = Combined scores on auditory and visual verbal memory tasks

All significant main effects and interaction effects were analyzed as predicted. As well, results were graphically represented to illustrate significant interactions. A Planned Comparisons procedure was followed in cases where individual cell means were to be compared to test specific hypotheses.

All statistical tests were computed using a Statistical Analysis System (SAS) subprogram. Planned Comparison Tests needed for inter-cell comparisons were computed by hand according to the formula presented in Snodgrass (1977).

Chapter III

RESULTS

Table 3 contains the raw and converted score means and standard deviations for all of the dependent measures. In order to illustrate meaningful comparisons across all variables (as suggested in Rourke, et al., 1983), all data for the dependent measures were converted into standardized I-scores, based on the mean and standard deviations of the normal control subjects (Group C) tested. Figure 1, graphically represents the two learning-disabled (RD and AD) groups in reference to the control subjects ($M = 50$, $SD = 10$). The I-scores have been adjusted so that good performance is represented in one direction (above 50) and poor performance is represented in the opposite direction (below 50). A general trend is apparent from the graph; namely, that the RD group fared poorly on memory tasks of a verbal nature and the AD group fared poorly on nonverbal memory tasks. Generally, strengths were also shown in the opposite realm for each of these groups.

To simplify the statistics and hypotheses to be discussed, a summary of the five sets of hypotheses, dependent variables compared, statistics used, general predictions, and experimental results is presented in Table 4.

Table 3 - Means (standard deviations) for all dependent measures, contrasted by group membership

<u>GROUPS =</u>				
<u>MEASURES</u>	<u>RD</u>	<u>AD</u>	<u>C</u>	
Recall Verbal Condition A	2.73(1.10)	3.08(1.51)	3.29(1.75)	
Recall Verbal Condition B	5.36(.67)	4.83(1.47)	6.03(1.14)	
Recall Verbal Condition C	3.73(1.62)	5.33(1.61)	5.71(1.74)	
Recognition Verbal Condition D	7.36(1.50)	8.08(1.62)	7.68(1.33)	
Recognition Verbal Condition E	8.27(1.62)	7.67(1.92)	7.84(1.66)	
% Phonetic Errors (Rgn. Tasks)	71.27(32.25)	55.27(33.34)	76.13(20.81)	
Rhyme Production Task	20.27(5.24)	26.08(6.42)	26.19(7.12)	
Auditory-Verbal Index	12.18(2.18)	13.00(3.05)	13.55(2.88)	
Visual-Verbal Index	9.09(1.92)	10.17(2.25)	11.74(2.08)	
Verbal-Recall Index	8.20(2.34)	10.35(2.06)	12.05(2.10)	
Verbal-Recognition Index	15.64(2.54)	15.75(2.77)	15.52(2.16)	
Rey-Osterrieth Nonverbal Task				
Total Copy Accuracy	60.18(5.46)	56.92(7.43)	63.42(1.75)	
Total Recall Accuracy	39.55(9.71)	30.25(9.16)	38.84(9.03)	
% Retained Copy - Recall	64.45(14.25)	53.75(16.41)	61.19(13.92)	
Organization Score	3.23(1.13)	2.79(1.05)	3.05(1.16)	
% Gestalt Retained	73.00(14.91)	61.75(20.79)	66.87(16.19)	
% Internal Retained	50.82(20.78)	39.50(18.68)	52.74(20.43)	

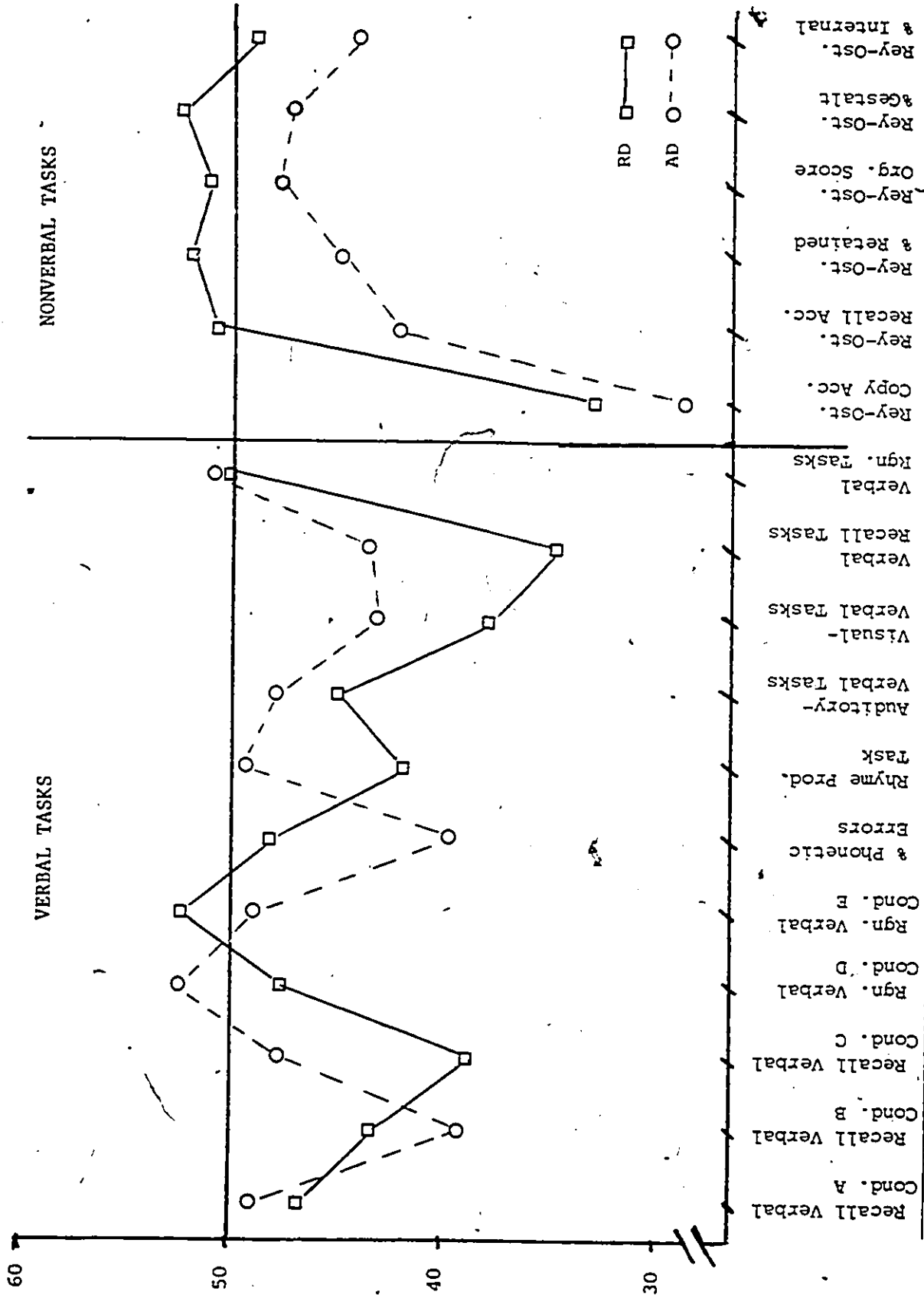


FIGURE 1 - T-Scores for all Memory Tasks (N = 50, SD = 10)

Table 4 - Summary of hypotheses, variables, predictions, statistics and results

<u>HYPOTHESIS</u>	<u>VARIABLES</u>	<u>EXPECTED</u>	<u>STATISTICS</u>	<u>OBTAINED</u>
1	T-score-Cond.A T-score-Cond.B T-score-Cond.C T-score-Cond.D & Retained-Copy to recall, Rey-Ost.	RD, AD < C	MANOVA	YES
2(a)	T-scores (based on Group C means) (a) Verb. Cond.A (b) & Retain Copy to Recall Rey-Ost.	(Groups x Tasks): RD < AD, C (Verb) AD < RD, C (Nonverb)	2-way ANOVA	NO
2(b)	Combined raw scores Aud. (Cond B+D) Vis. (Cond C+E)	(Groups x Modality): RD < AD, C (Aud) AD, RD < C (Vis)	2-way ANOVA	NO
3	Raw scores-Rey-Ost. Copy Accuracy Recall Accuracy Organization-Recall & Gestalt features & Internal features	AD < RD, C (Groups x Features) AD < RD, C (Ges) RD < AD, C (Int)	1-way ANOVA 1-way ANOVA 1-way ANOVA 2-way ANOVA	YES YES NO NO
4(a)	&Phonetic (rhyming) errors, verbal rgn tasks	RD < AD, C	1-way ANOVA	NO
4(b)	Raw score-Rhyme Prod. Task	RD < AD, C	1-way ANOVA	YES
5	Combined raw scores Rcl (Cond. B+C) Rgn (Cond. D+E)	All groups: Rcl < Rgn Recall tasks only: RD, AD < C	2-way ANOVA	YES

A. Hypothesis 1 - General Mnestic Skills

A one-way MANOVA was performed across all five memory variables. While raw recall/recognition scores (converted to I-scores) were used for Verbal Conditions A, B, C, D, and E, it was decided to use percentage of items retained from Copy to Recall on the Rey-Osterrieth task. This was done in order to control for differences in the Copy accuracy scores between groups (i.e., AD children copied fewer elements than did the other groups in the original phase of the task, thereby likely reducing the number of elements available for later recall). While Verbal Condition A also involved both copy and recall phases, no converted per cent score was necessary as all subjects copied 100% of the stimulus words in the original phase of the task.

Using the Hotelling Lawley Trace criterion, the MANOVA performed on the various dependent measures converted to I-scores revealed a clearly significant Group effect ($F(12, 90) = 2.64, p < .005$). According to some research sources (e.g., Bray & Maxwell, 1982), the statistically significant MANOVA lowers the risk of Type I errors associated with multiple univariate analyses (as are present in the current research design) and thus 'protects' further univariate tests. Therefore, the MANOVA indicates statistically significant differences between learning-disabled and non-disabled subjects using a general index of 'memory skill' comprised of various verbal and nonverbal memory tasks. A

graphic illustration, comparing the three achievement groups (RD, AD, C) on the percentage of items remembered for each of the five memory tasks is presented in Figure 2. It was arbitrarily decided to utilize percentage of items recalled across all variables as a standard means of graphing and comparing measures with different base units. As can be seen from Figure 2, while much overlap is apparent in the performances of Verbal Conditions B and E, the control group C exhibited the highest scores on three of the five memory variables, while the RD group obtained the lowest scores on three of the five memory variables. The general similarity in graph shape across groups (Figure 2) is also noteworthy, suggestive of consistencies in task difficulty for all subject groups. Differences in task difficulty across groups have concerned researchers in this field (Jorm, 1983), as differences may indicate that various forms of information processing are required, thus rendering the inter-task and inter-group comparisons meaningless. The results of this analysis clearly support Hypothesis 1, the general prediction that disabled groups RD and AD do not perform as well as their normal counterparts overall on short-term memory tasks.

B. Hypothesis 2 - Type and Modality of Memory Tasks

Comparing task performances along the Verbal/ Nonverbal dimension, a 2 x 3 ANOVA was created, in a Repeated Measures procedure using the T-scores of the two chosen tasks (Verbal

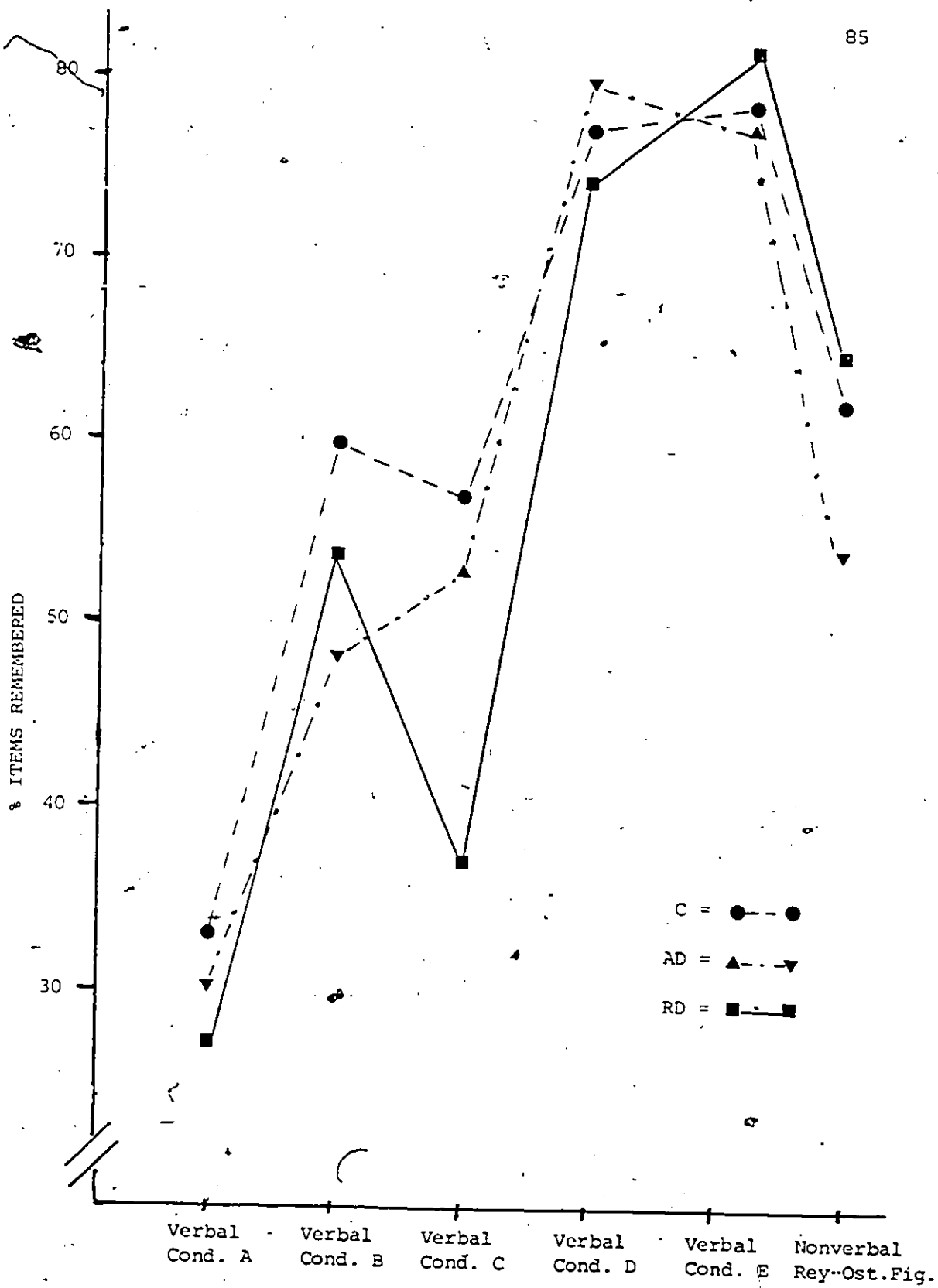


FIGURE 2 - Percentage of Items Recalled Across Memory Tasks

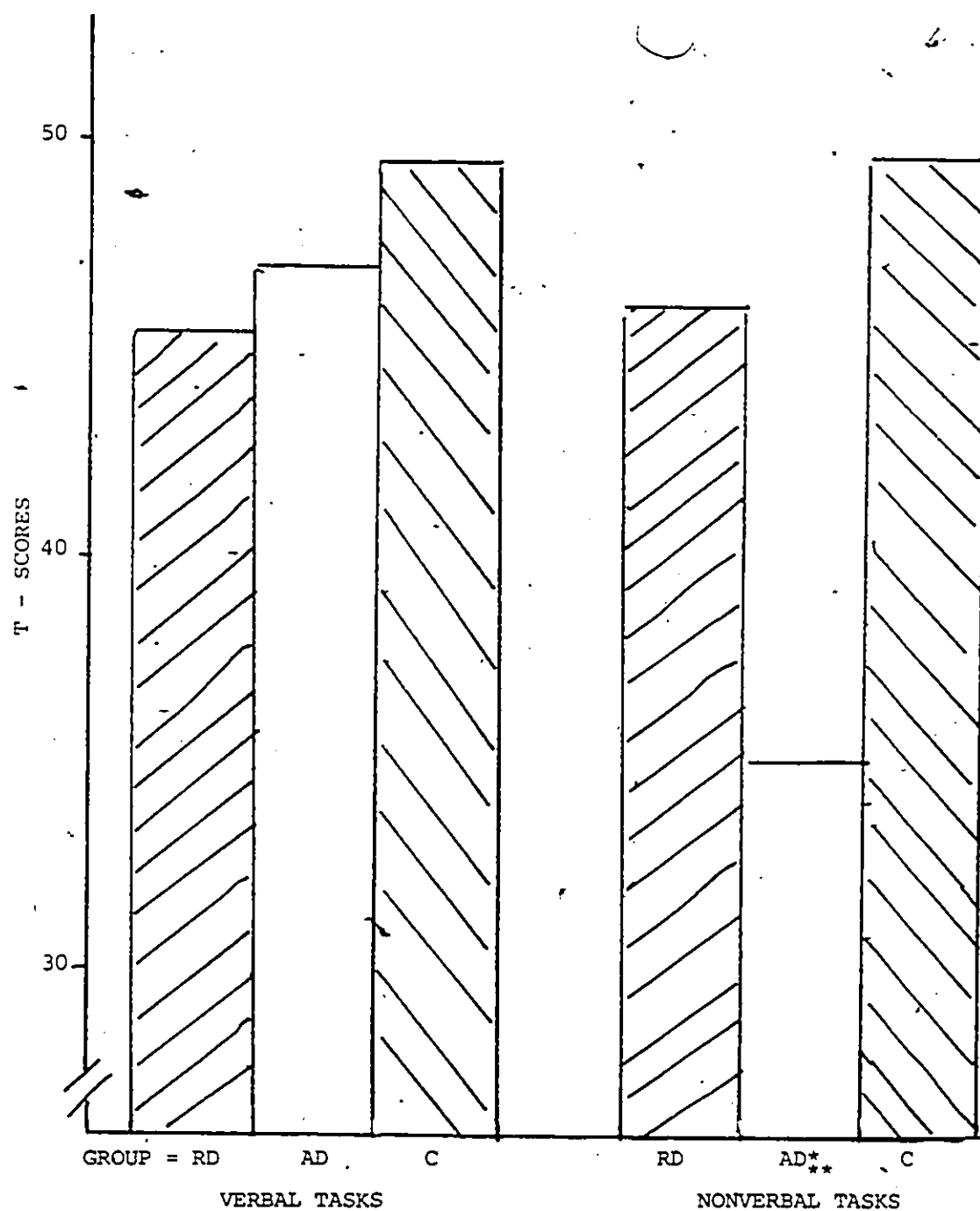
Condition A and the Nonverbal Rey-Osterrieth Task) as two levels of the new variable 'Type Task' and comparing the converted scores across subject groups. It was decided to use I -scores to control for differences in level of difficulty between the two tasks by comparing each to a common reference point.

The E -test for the ANOVA did not approach commonly accepted levels of statistical significance for either main effect (Type-task: $E(1,51) = .05$, n.s.; Group: $E(2,51) = .91$, n.s.) or for the Task x Group interaction ($E(2,51) = 1.55$, n.s.). (Summary tables for these and other univariate analyses are contained in Appendix D.) Furthermore, individual Planned Comparison tests between individual cell means did not show any differences (RD - C group comparison on the Verbal task $E(1,51) = 1.01$, n.s.; AD - C comparison on the Nonverbal task $E(1,51) = 2.26$, n.s.). Therefore, the prediction that AD children would perform poorly on a Nonverbal memory task while RD children performed poorly on a Verbal memory task was not upheld by the results of this analysis.

Nonetheless, while a comparison of these particular Verbal and Nonverbal measures did not result in the predicted dissociation of memory skills between the RD and AD groups, more comprehensive Verbal and Nonverbal indices were produced by combining and averaging all of the non-redundant dependent measures (Verbal Memory index includes scores on Conditions A, B, C, D, and E;

Nonverbal Memory index includes Rey Osterrieth Gestalt and Internal Copy scores, Gestalt and Internal Recall scores, Copy and Recall Organization scores). Statistical analyses performed on these composite measures suggest the predicted differences in memory skill. (Figure 3 illustrates this comparison; each bar on the graph represents the summed and averaged \bar{I} -scores for the respective Verbal and Nonverbal memory task scores.) MANOVAS calculated for the separate Verbal and Nonverbal Indices revealed significant between-groups differences: Hotelling-Lawley Trace for Verbal tasks: $E(10,92)=2.66$, $p < .01$; Hotelling-Lawley Trace for Nonverbal tasks $E(12,90)=2.28$, $p < .02$. The greatest differences appeared between RD and C groups on the Verbal index and between AD and C groups on the Nonverbal index.

This latter result was further explored through a two-way (Group x Material Type) ANOVA on the combined \bar{I} -scores: The main effect for Group ($E(2,48)=4.09$, $p < .09$) and the Group x Task interaction ($E(2,48)=2.99$, $p < .10$) approached accepted levels of statistical significance. A post hoc Neuman Keuls analysis revealed a significant discrepancy between the AD group's Nonverbal (very poor) and Verbal (average) Memory Indices (critical value=69.7). The low AD Nonverbal Index was also found to be inferior to both Verbal and Nonverbal Indices of Groups RD and C. No other inter- or intra-group comparisons (i.e., comparing the RD group's Verbal and Nonverbal Index scores) were found to be



* Nonverbal AD < Verbal AD, **Nonverbal AD < Nonverbal, Verbal RD, C

FIGURE 3 - Comparison of Verbal and Nonverbal Memory Performances Across Groups

significantly different from each other.

To compare the groups' task performances according to modality of verbal task (Auditory/ Visual), another 2 x 3 ANOVA was performed. A "Modality" variable was created through a Repeated Measures procedure with Auditory and Visual (combined scores of the recall and recognition tasks in each modality) as the two levels of this new variable. The results of this analysis are illustrated in Figure 4. As can be seen, the predicted Group C superiority on both types of verbal tasks and Group RD inferiority on these tasks obtains. Tests for the main effects for Group ($E(2,51) = 2.01$, n.s.) and for Modality ($E(1,51) = .18$, n.s.) were not found to be statistically significant.

The predictions concerning the interaction of Group x Modality were not supported statistically ($E(2,51) = .11$, n.s.). Planned Comparisons Tests comparing the individual cell means revealed the following: As predicted, the AD group performed as well as Group C on auditory tasks ($E(1,51) = 1.05$, n.s.), although the expected AD inferiority to Group C on visual tasks did not obtain ($E(1,51) = .51$, n.s.). Group RD did not perform significantly worse than Group C on either auditory or visual tasks, as predicted in Hypothesis 2(b) (Auditory $E(1,51) = 1.51$, n.s.; Visual $E(1,51) = 2.92$, n.s.). Similarly, the predicted RD inferiority on auditory tasks did not obtain when comparing RD and AD groups in this

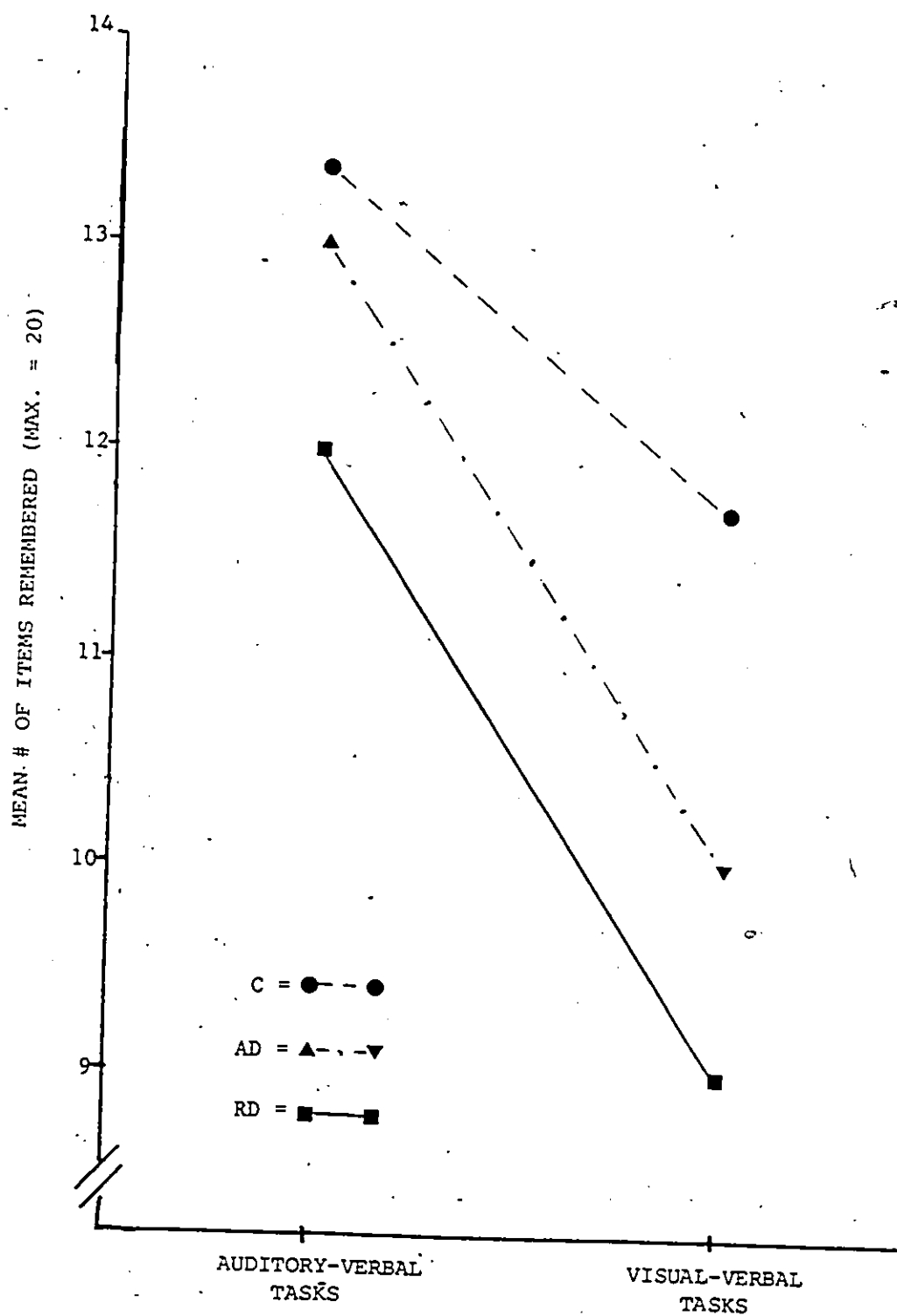


FIGURE 4 - Comparison of Modality Variable Across Verbal Memory Tasks

modality ($E(1,51) = .04$, n.s.). Generally, the hypotheses made in relation to the modality of verbal tasks were not supported, as the predicted dissociation between visual and auditory tasks for RD and AD groups did not obtain.

C. Hypothesis 3 - Nonverbal Memory Task Comparisons

The three learning-achievement groups were compared on their performances of the Rey-Osterrieth Nonverbal Memory Task, both Copy and Recall phases, in a series of one-way ANOVAs. One-way analyses revealed highly significant differences between groups on Copy accuracy ($E(2,51) = 9.40$, $p < .0005$), and less robust differences, though statistically significant, in Recall accuracy ($E(2,51) = 4.27$, $p < .05$ - marginally significant with Bonferroni adjustment). However, the Organizational scores for the Recall performances did not reveal the between-group differences which were predicted ($E(2,51) = .44$, n.s.).

Individual Planned Comparison statistics computed for the Copy and Recall accuracy performances revealed Group AD obtained lower mean Copy scores than did control subjects ($E(1,51) = 18.73$, $p < .001$); significant differences also obtained when comparing Groups AD and RD (AD was expected to perform measurably worse $E(1,51) = 5.34$, $p < .05$). Similarly, Group AD performed significantly worse in Recall Accuracy than did Group C ($E(1,51) = 7.55$, $p < .01$) and also differed from Group RD, as predicted ($E(1,51) = 5.87$,

$p < .05$). Figure 5 presents these results in graphic form. With the exception of the Organizational score analysis, these results strongly support Hypothesis 3(a) with respect to poor Copy and Recall Accuracy in the AD group.

The prediction made in relation to greater drops in performance between Copy and Recall was supported, as the AD group decreased an average of 26.67 (41%) accuracy points from Copy to Recall, while RD and C groups decreased an average of 20.63 (32%) and 24.58 (38%) accuracy points, respectively. This finding is particularly relevant in light of the poorer overall copy scores which AD children obtained in the first phase of the task. Put another way, AD children appear to be doubly hampered on this test: Their poor copy accuracy limits the amount of information they encode in memory stores; this is compounded by a greater tendency to 'lose' information in storage, either because of poor retrieval or other faulty mechanisms.

To further test Hypothesis 3(b) the quality of Rey Osterrieth Nonverbal Recall performances was analyzed using a 2 x 3 (Feature x Group) ANOVA; the 'Feature' variable was created through a Repeated Measures procedure with raw scores (converted to T-scores to control for absolute number of items recalled, as Gestalt and Internal scores are based on different scales) of Internal and Gestalt features recalled as the two levels of this.

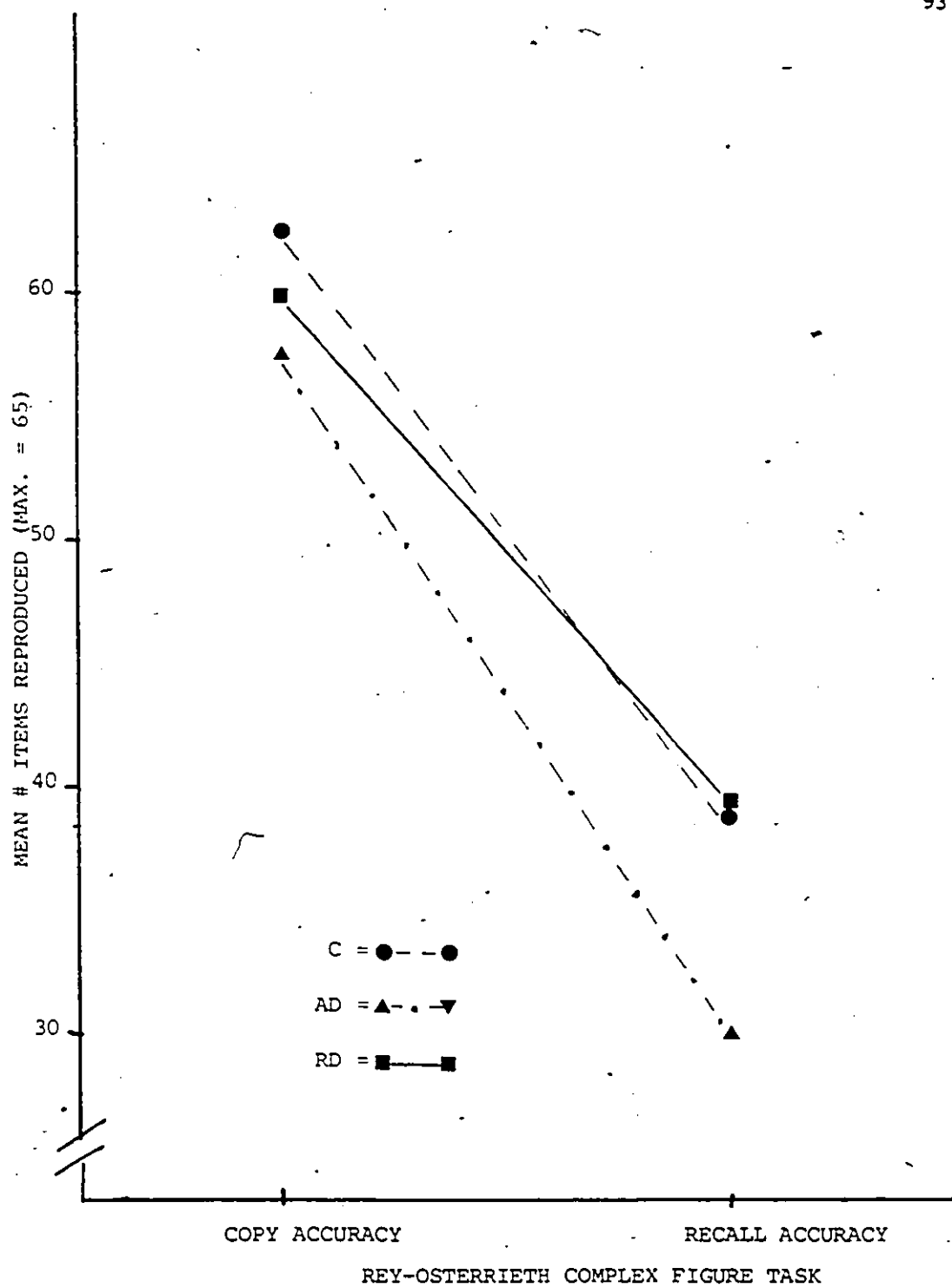


FIGURE 5 = Comparison of Copy and Recall Accuracy, Nonverbal Memory Task

new variable. This analysis showed a statistically-significant main effect for Group ($E(2,51) = 4.33$, $p < .02$). The tests for main effect for Feature type ($E(1,51) = 1.82$, n.s.) and the Group x Feature interaction ($E(2,51) = .83$, n.s.) did not reveal any differences. The Planned Comparisons suggested no support for the predicted RD inferiority on Internal features ($E(1,51) = .45$, n.s.), nor was the AD group found to be inferior to Group C on the recall of Gestalt items ($E(1,51) = 2.45$, n.s.). However, AD children were shown to be significantly inferior to the RD group on Gestalt items ($E(1,51) = 5.33$, $p < .05$). These results are shown in Figure 6. The RD superiority in recall of Gestalt features is noteworthy, and the inferiority of the AD group is in the predicted direction.

A second 2 x 3 (Group x Feature) ANOVA was computed, using the percentage of Gestalt and Internal items retained from copy to recall phases. This second analysis was performed in order to control for differences in copy accuracy between groups, a confounding factor which ultimately limits the amount of information available for recall (particularly for AD children who are poorest in copy accuracy). The results of this analysis are shown in Figure 7. Although tests for the main effect for Group ($E(2,51) = 2.10$, n.s.) and the interaction of Group x Feature ($E(2,51) = .84$, n.s.) did not show statistically significant differences, the main effect for Feature type did result in significant differences ($E(1,51) = 32.15$, $p < .0005$), with better retention of Gestalt than

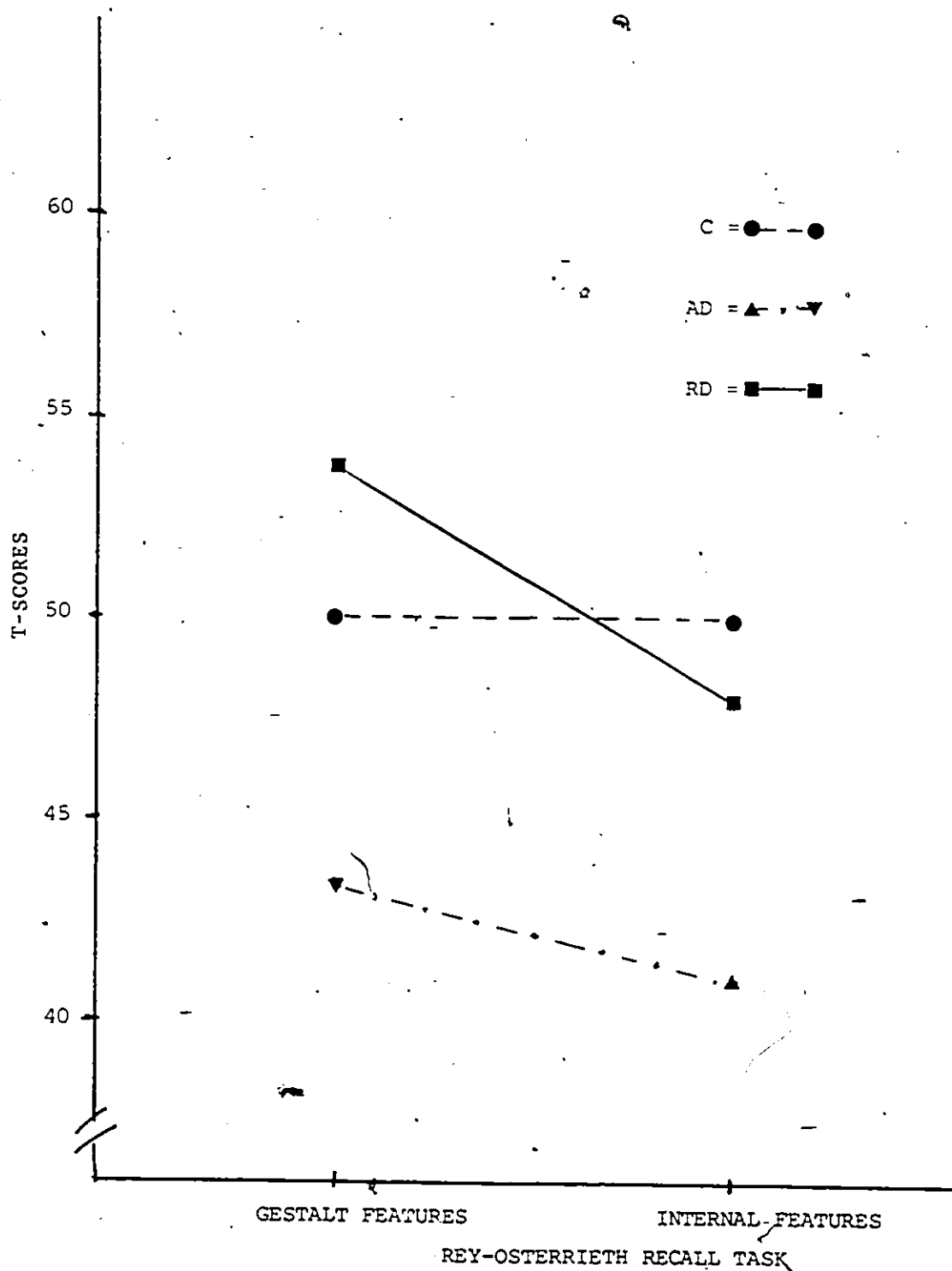


FIGURE 6 - Comparison of Feature Type, Nonverbal Memory Task, Based on Raw Scores for Items Recalled

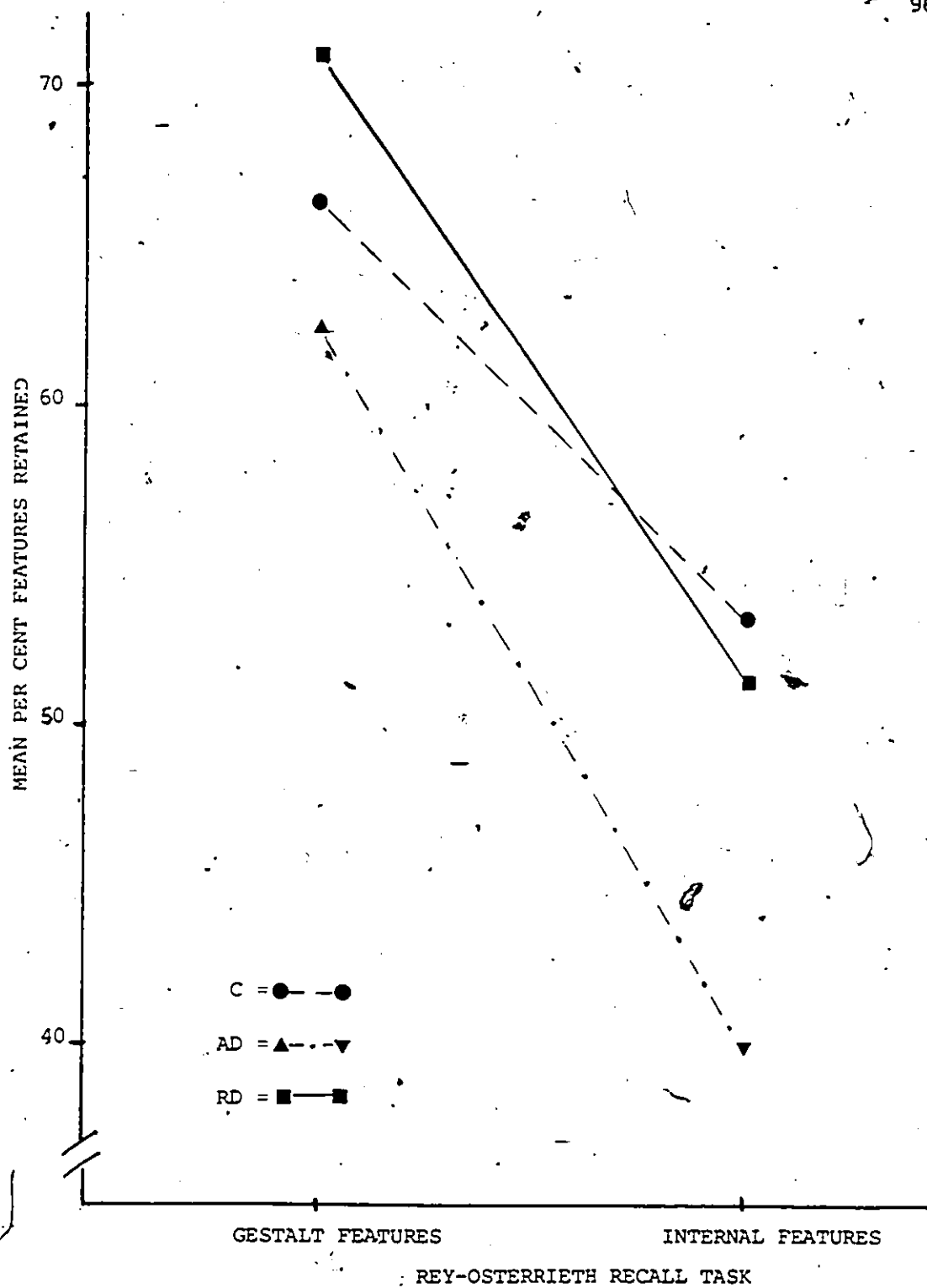


FIGURE 7 - Percentage of Features Retained from Copy to Recall Phases on Nonverbal Memory Task

Internal features across all subject groups. This analysis reflects similar findings to the Group x Feature ANOVA computed with unconverted recall scores (compare Figures 6 and 7), although the greater drop in retention of Internal elements becomes far more apparent when comparing per cent retained across groups.

Planned Comparison tests for individual cells which were predicted to be significantly different revealed no support for the specific hypotheses. That is, the comparisons failed to show that Group AD had particular difficulty, in comparison to RD ($E(1,51) = 2.81$, n.s.) and C groups ($E(1,51) = .88$, n.s.), recalling Gestalt elements and, conversely, that Group RD had particular difficulty recalling Internal elements (RD - C comparison: $E(1,51) = .12$, n.s.).

Indeed, the RD group performed better than the AD group on the Internal element measure, in direct contrast to the hypothesis concerning the two types of nonverbal features. Generally, these results suggest that it is the type of feature being retained, rather than group membership, which differentiates retention of nonverbal material. Furthermore, the groups are far less different from each other when differences are controlled for in initial copy accuracy.

D. Hypothesis 4 - Phonetic Encoding and Memory Skills

Percent of phonetic errors on Visual and Auditory Recognition tasks was compared between subject groups using a simple

one-way ANOVA. It was decided to utilize the percentage of total errors which were phonetic (rhyming) in nature in an effort to control for individual and group differences in total number of errors. For example, a subject's obtaining two phonetic errors out of two errors in total is expected to be more clinically meaningful than obtaining five errors, only two of which are phonetic; this method is also consistent with previous research into the phonetic memory issue (e.g., Liberman, et al., 1982).

This analysis revealed between-group differences approaching statistical significance using the Bonferroni adjusted probability scores ($F(2,49) = 2.52, p < .10$). However, an unexpected result was the significantly inferior score of the AD group on this index. The Planned Comparison test between the RD (expected to be the lowest group on this measure) and C mean scores failed to reach the expected result ($F(1,49) = .07, n.s.$). Figure 8 displays the proportion of phonetic errors relative to total errors on the Verbal Recognition tasks. It is interesting to note that, while only slight differences exist between groups in total error rate, the groups are more clearly differentiated when comparing phonetic error rate. The relationship of the ability to attend to the phonetic characteristics of verbally-encoded stimuli to general memory task strategy will be discussed in greater detail in the next section, in light of the unexpected results for the AD (known to be a strong verbal skills) group.

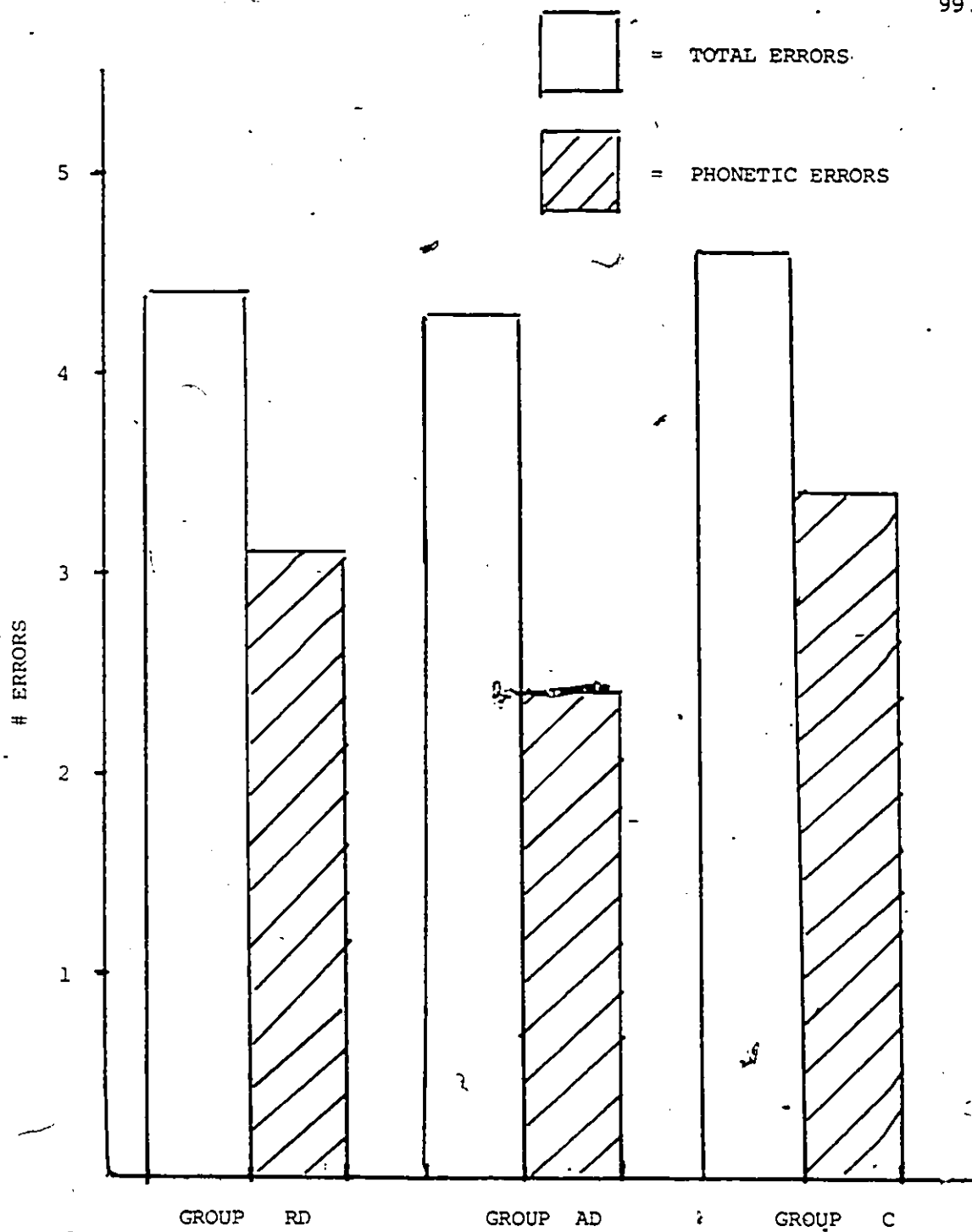


FIGURE 8 - Total Error Rate Contrasted by Phonetic Error Rate, Verbal Recognition Tasks

Raw scores on the Rhyme Production Task were also compared using a simple one-way ANOVA. Results indicated statistically significant differences between groups ($E(2,51) = 3.45, p < .05$ - marginally significant with Bonferroni adjustment). The Planned Comparison test supported the experimental predictions, as the RD group obtained significantly poorer mean scores on this task than both C ($E(1,51) = 6.46, p < .05$) and AD ($E(1,51) = 4.40, p < .05$ - marginally significant with Bonferroni adjustment) groups. This phonetic variable is graphed in Figure 9 to illustrate the statistical findings.

E. Hypothesis 5 - Format of Verbal Memory Test

The different Formats of verbal memory test were compared using a 2 x 3 (Format of Test x Group) ANOVA. The 'Format' variable was created using a Repeated Measures procedure with the two formats of testing verbal memory, Recall and Recognition (combining Visual and Auditory task raw scores for each), as the two levels of the new variable. The results of this analysis are presented in Figure 10. Although the test for the main effect for Group did not show statistically significant differences ($E(2,51) = 2.21, n.s.$), the predictions concerning Format of test ($E(2,51) = 168.33, p < .0005$) and the Group x Format interaction ($F(2,51)=5.04, p<.01$) were strongly supported. As predicted, all groups performed significantly better with Recognition than Recall Format of test. Individual Planned Comparison tests

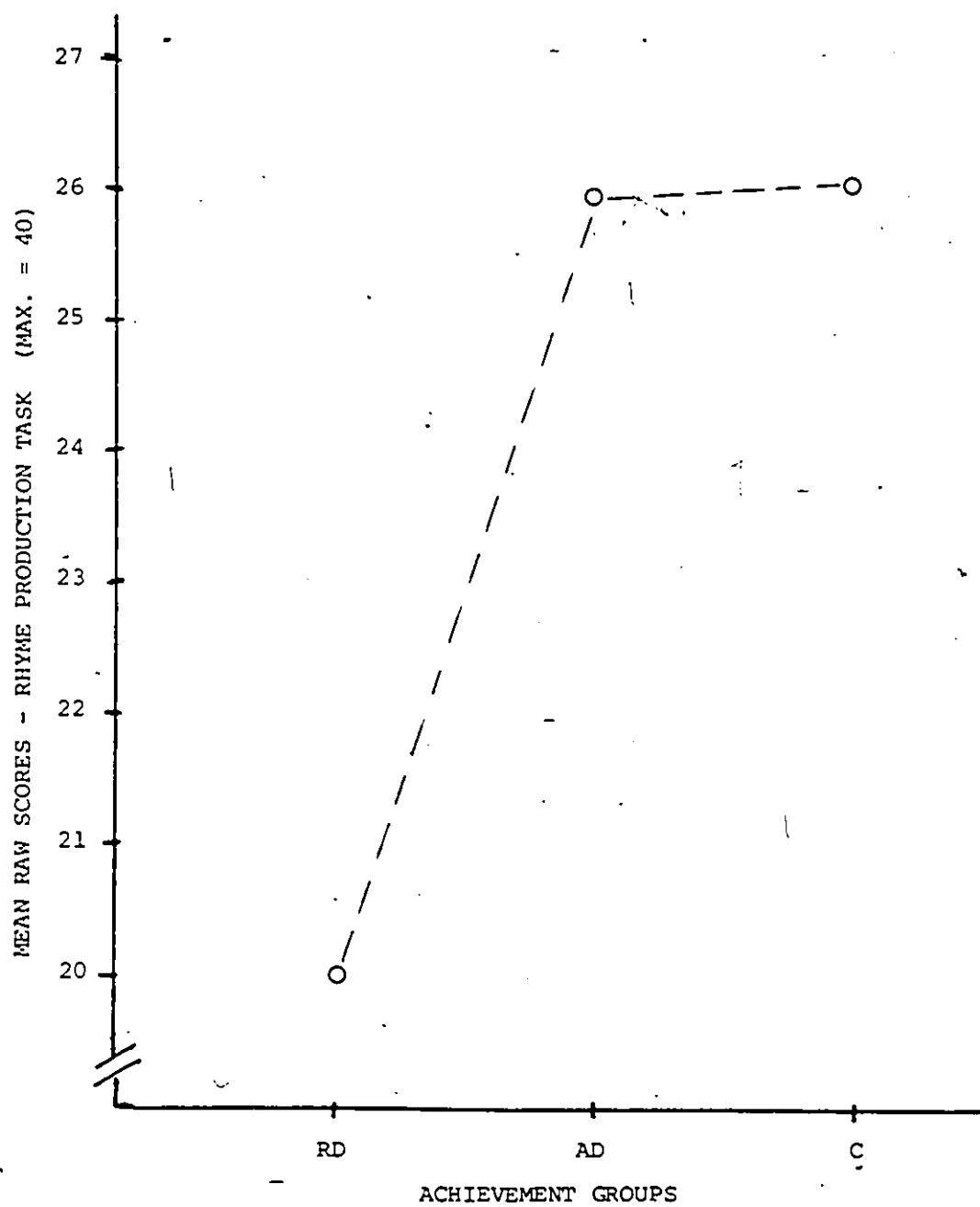


FIGURE 9 - Raw Scores on Rhyme Production Task

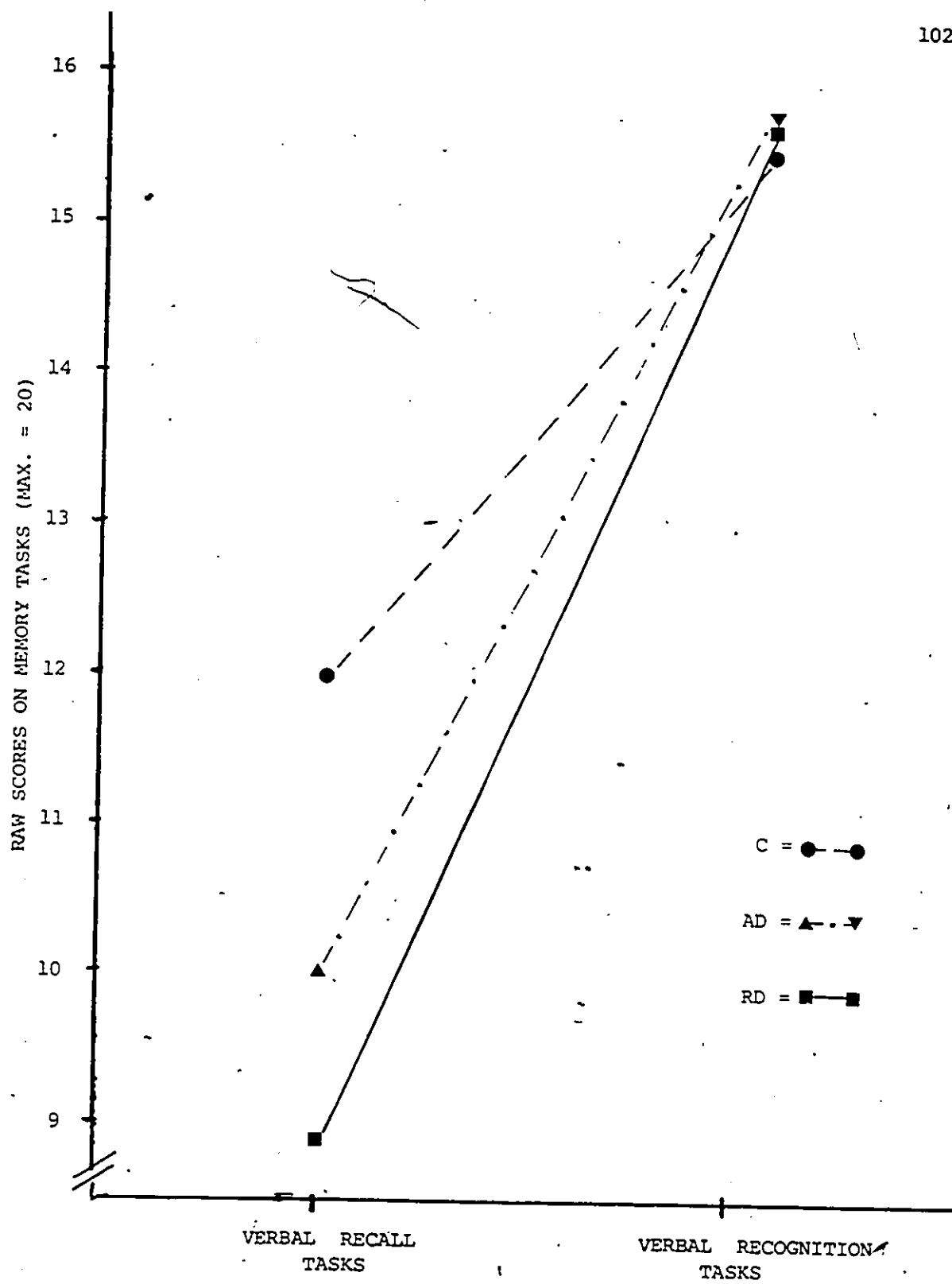


FIGURE 10 - Comparison of Test Format, Verbal Memory Tasks

revealed that both learning disabled groups, RD and (to a lesser extent) AD, obtained lower mean scores than C subjects in the Recall Format of Verbal memory tests ($RD < C$, $F(1,51) = 15.67$, $p < .001$; $AD < C$, $F(1,51) = 5.90$, $p < .05$). This latter finding also directly supports Hypothesis 5.

Chapter IV

DISCUSSION

A. 'General' Memory Ability

The support for Hypothesis 1, relating to general differences in mnemonic skills between learning-disabled (with primary deficiencies in Reading and Arithmetic) and non-disabled children is consistent with the large body of LD-memory research on both the RD (e.g., Rourke & Finlayson, 1977; Lyon et al., 1981, 1982; Jorm, 1983) and AD learning subtypes (e.g., Siegel & Feldman, 1983; Siegel & Linder, 1985). Moreover, this well-documented result has obtained in the present study despite the use of entirely different verbal and nonverbal memory tasks, and the comparison of two homogenous LD subtypes in a single study. (Fletcher, 1985b, and Siegel and Linder, 1984, are among the few previous researchers to date who have compared both RD and AD subtypes on memory tasks in one study.) This lends further support to the experimental literature in psychology and education which has also repeatedly established the existence of memory deficiencies or inefficiencies in disabled learners. These findings also provide confirmation for parents' and teachers' day-to-day reports that the child with learning disabilities often presents with memory difficulties on a wider range of non-academic tasks which render even simple activities complex and frustrating for both child and adult.

The experimental memory research has attributed this general result to a number of underlying factors, from direct 'memory breakdowns' such as deficient encoding and rehearsal (Bauer, 1977; Byrne & Arnold, 1981; Cohen et al., 1984), poor retention of information (Done & Miles, 1978), and a 'trade-off' between memory 'processing and storage' (Daneman & Carpenter, 1980), to indirect 'non-memory' processes, such as deficient attentional or purposive processing capabilities (Ceci, 1983, 1984) in specific modalities or with distinct types of material (e.g., the phonological processes studied by Liberman et al., 1982; the sequential/simultaneous nature of tasks studied by Das et al., 1978). Torgeson (1985) has suggested that three inter-related factors may account for impairments in LD children's memory: In addition to the impaired memory processes just discussed, he considers the influences of (1) poor use of 'control processes', the appropriate task strategies which facilitate memory (e.g., chunking, elaboration), and (2) deficits in the knowledge base of LD children, thereby making new material less personally meaningful.

While compelling support for one or other of these hypotheses has been gained in various avenues of research, the present study was aimed at further elucidating the prominent theories relating to type of information encoded (verbal/nonverbal, gestalt/internal features), modality (visual/auditory), and format of test (recall/recognition). A further intent was to relate these between

and within-group differences more generally to what is already known about the neuropsychological profiles of these children. The educational implications for these 'hard to serve' children are great, and specific recommendations are offered, in light of the present results, to aid these children and those working with them to take best advantage of intact cognitive skills. Finally, the complexity of the issues warrants due consideration of the notion of 'memory' as such - i.e., are all of these tasks equivalent in their ability to tap into the evasive 'storage' process or are some tasks thought of as 'memory' tasks truly a unique function of another related cognitive process?

While direct support was not found for Hypothesis 2(a) as it was designed, comparing RD, AD, and Control subjects on Verbal and Nonverbal incidental memory measures, it appeared that the failure of this analysis lay in the measures chosen for comparison. Verbal Condition A, designed as a Verbal corollary of the Rey-Osterrieth complex nonverbal figure task, with both copy (to insure proper active encoding of material) and 20-minute delayed recall phases, in an incidental memory paradigm, did not discriminate between any of the groups. In examining the raw data, this appears to be related to (1) a heightened level of task difficulty producing a 'floor effect' whereby almost no child (even non-disabled Group C children) recalled more than 50% of the words on the list; and (2) the generally low variance on the task,

in which few children in any group strayed from the 20-50%-recall range.

Furthermore, as a measure of incidental recall, this verbal task, particularly in comparison to the well-studied Rey-Osterrieth nonverbal task, appeared to be hampered by having only a few elements (maximum number of words = 10) needing to be copied, resulting in a much shorter exposure time during the copy phase. (Most children required only 30 - 60 seconds to copy the entire list, compared to a 120-300 second copy phase on the Rey-Osterrieth task.) It could therefore be argued that the cognitive activity or 'purposive processing' (Hasher & Zacks, 1979) imposed in the copy of a short list of common words does not lead directly to 'deeper' levels of encoding (Craik & Lockhart, 1974) as efficiently as the novel and more complex drawing activity of the Rey-Osterrieth task. Word copying would appear to be a rote, and probably for many 10-14 year old children, quite automatic daily activity that probably places few demands on attentional or cognitive resources (although it can be argued that this may not be the case for RD children). This possibility would certainly be supported by some of the children's self reports: For example, one Control subject remarked that he was unable to recall any of the Condition A words because he had been so engrossed in the intervening task (WRAT Arithmetic subtest) and had 'paid no attention' to copying the words earlier.

Thus, to correct for these possible task-related difficulties, the Verbal-Nonverbal dimension was explored in greater detail by summing and averaging several tasks of each type. With the confounding effects of poor task construction and questionable levels of task equivalence/ 'discriminating power' (Jorm, 1983) controlled for, the predicted Verbal/Nonverbal memory task dissociation between groups resulted. This would appear to be consistent with the two-tiered working memory model proposed by Baddeley and Hitch (1974). That is, verbal material is processed through an 'articulatory loop' before reaching long-term semantic stores while nonverbal material is processed through a nonverbal memory corollary, the 'visual scratch pad'. What follows, as suggested by the present results, is that an individual may have difficulty with one of these systems while the other system continues to process information of its respective mode with relative ease.

However, it is important to note that the RD children obtained only slightly poorer scores than Control subjects on the composite index of Verbal memory, a less-robust effect than what might be expected on the basis of previous investigations into RD verbal memory functions (e.g., Brady, et al., 1983; Cohen et al., 1984) and other verbal-processing skills (e.g., Doehring, 1983; Petrauskas & Rourke, 1979; Rourke & Finlayson, 1977). Despite the averaging of Verbal condition scores, poor test construction may still be

limiting the amount of between-group differences. Another difference between this and many of the previous memory studies is the older age of the subject groups in the present research. RD children in the primary grades (the age group most frequently studied - e.g., Ozols & Rourke, *in press*) appear to be particularly different from their normal counterparts on verbal processing and verbal memory tasks (Ozols & Rourke, *in press*). In contrast, the present study's finding that AD children were particularly poor in the encoding and recall of nonverbal material was clearly consistent with the limited body of previous research into this subtype of disabled learners (Fletcher, 1985b).

B. Verbal Memory Skills - Specific Aspects

1. Modality

Exploring the verbal memory skills of both RD and AD children in more detail, the distinction of modality of presentation (and response) did not produce the expected result: namely, that AD children would have modality-specific difficulties with visual-verbal material (as reported by Siegel & Feldman, 1983; Siegel & Linder, 1984) and that RD would have difficulties with verbal material in either visual (Corkin, 1974; Gerber & White, 1983) or auditory modalities (Cohen et al., 1984; Farnham-Diggory & Gregg, 1975; Holmes & McKeever, 1975; Koppitz, 1975; McKeever & VanDeventer, 1975; Ritchie & Aten, 1979).

It was thought that the predicted results may have been obfuscated by combining Recall and Recognition raw scores for each modality. However, upon repeating these analyses, the Recall-only ANOVA (comparing Conditions B and C across groups) revealed somewhat unexpected results: Individual comparisons discriminated AD and C groups on the Auditory measure, while RD performed in an inferior fashion to both AD and C groups on the Visual task only. No significant differences obtained between groups when comparing them on Recognition tasks (Conditions D and E). Thus, these results do not support the modality-related inter-group predictions in any consistent fashion.

To elucidate this issue, it is important to delve more closely into the body of relevant research, making careful comparisons and contrasts with the materials and paradigms used. Generally, the studies which have reported modality-specific differences employ shorter stimulus and reaction times, and often artificial, tachistoscopic (Bouma & Legein, 1980; Pelham, 1979; Stanley & Hall, 1973) or dichotic presentations (Cohen et al., 1984; McKeever & VanDeventer, 1975). These studies have frequently focused at accessing immediate 'sensory' memory. A further difference between the majority of those studies and the present one is the reliance on non-meaningful (e.g., digit and letter strings -- Byrne & Arnold, 1981; Koppitz, 1975) or non-codable stimuli (e.g., CVC trigrams -- Liberman et al., 1982). Some previous studies

reporting modality differences have even erred in confounding modality-equivalence by actually using different types of material (e.g., visual [nonverbal] pictures vs. auditory [verbal] words -- Estes & Huizinga, 1974).

It would appear that the present verbal memory tasks, which utilized words (with their inherent semantic aspects) and somewhat longer intervals between stimulus and response, placed fewer demands on limited-capacity modality channels. It is possible that this state of affairs thereby enabled the children to process the words past modality-dependent immediate memory stores into semantic memory (Lindsay & Norman, 1977), effectively obscuring any modality-specific strengths/weaknesses between groups. These results suggest that modality of presentation is a pre-semantic variable primarily relevant only at the initial sensory input/immediate memory stage (Stanley & Hall, 1973). One study directly addressing this issue suggests that a child's 'impaired modality' pathway (as assessed by performance on visual and auditory 'span' tests) will produce difficulties at time of presentation, but specific difficulties can be sufficiently alleviated by purposive semantic coding into the single semantic system (Ceci, et al., 1980).

Furthermore, many of the previous verbal memory studies suggesting difficulties in both modalities for RD children (little

research in this area is done with AD children) have noted the strong negative effect which serialization of stimuli has on task performance (e.g., Corkin, 1974; Holmes & McKeever, 1979; Lindgren & Richman, 1984; Mason et al., 1975; Noelker & Schumsky, 1971). The free recall paradigm of the present study eliminated the serialization bias to an extent, although verbal memory tasks are always, by definition, serial in nature. The present results would suggest equivalent levels of verbal free recall in RD, AD, and C children, although a 'ceiling effect' (suggested in Figure 4) related to task difficulty may have resulted in obscuring any slight inter-group differences.

This evidence appears to hold considerable implications for the present educational controversy surrounding presentation of tasks and modality of examination for LD students. Crispin and her colleagues have stated in regard to the construction of modality-specific memory tasks "... the results of this comparison study suggest that pure (visual sequential) measures can only be achieved at the cost of practical relevance to reading" (1984, p. 30). Generally, modality of presentation appears to have little bearing on RD children's performances of the semantic memory tasks which largely comprise school learning. Furthermore, while one subtype of RD children has also been shown to have difficulty with the semantic memory system (Cohen & Netley, 1978), it is important to note that this more debilitating impairment is

uncommon in children with relatively high WISC PIQs (as in the present sample). One could thus conclude that variables relating to semantic encoding are likely far more relevant in applied settings; some of these variables will be considered in the next section.

2. Phonological characteristics

Another aspect of Verbal memory task performance investigated in the present study relates to phonetic coding ability. This was first assessed by comparing RD, AD, and C groups on their percentage of phonetic errors using a forced-choice recognition task with phonetically-similar foil words as some of the distractor items. While previous research comparing RD with normal subjects strongly suggests a lower phonetic error rate, or less-confusability with phonetically-similar stimuli (Brady et al., 1983; Mann et al., 1980; Mark et al., 1977), the present findings did not reflect similar tendencies. Age differences between studies may account for this difference, as some research suggests a tendency toward "more precise phonetic codes" in older RD children (Olson et al., 1984). It is also important to remember that the RD subjects assessed in the present study have all enjoyed the benefits of one or more years of intensive remedial education, one focus of which is drill work in phonetic decoding skills. The results of the present analysis may therefore reflect recent learning in the RD group.

In contrast, an unexpected AD group low percentage of phonetic errors obtained. Although one study showed young AD children to be similar to RD children, obtaining low phonetic error rates (Siegel & Linder, 1984), this was not expected, due to the older age group studied in the present research. This latter assertion was based on the research and clinical reports suggesting that older AD children have extremely well-developed phonetic coding skills (Strang & Rourke, 1985b). Nonetheless, the finding of a low percentage of phonetic errors in AD children may reflect similar tendencies to those reported in Rourke and Finlayson (1977). Despite the strong verbal nature of certain neuropsychological tasks, AD children often fare poorly as a function of task novelty (e.g., low average scores obtained on the Auditory Closure Test). A further AD-group phenomenon is suggested by Rourke and Finlayson's results with the Benton Sentence Memory Test; low average scores obtained by AD children are suggestive of difficulties with the semantic requirements of the test. This possibility is consistent with the present results, as the novel forced-choice nature of the tasks may have resulted in semantic confusions for these children. Semantic limitations may be suggested by the lower Verbal IQs found in the AD group (in contrast to high-average VIQs in Rourke and Finlayson's [1977] Group 3 subtype).

To clarify this matter, it is also important to consider the

results of the Rhyme Production Task analysis. In this instance, the predicted RD-group inferiority obtained and AD children performed as well as controls. This suggests, as reported by other specific-LD studies (Boder, 1973; Petruskas & Rourke, 1979; Ridgely, 1970) that RD children have especial difficulty appreciating or producing phonologically-related words, whereas AD children exhibit well-developed skills on rote phonological tasks. The memory task results with respect to phonological codes suggest two separate processes: phonological competence (poor in RD subjects) versus the ability to deploy this competence on a novel, semantically confusing memory task (poor in AD subjects). Perhaps, as other research and descriptions of this subtype of children suggest (Rourke, 1982; Strang & Rourke, 1985b; Tellier, 1986), generating a new strategy in an unfamiliar learning situation poses considerable difficulty for the AD child.

Whereas RD and C children were able (or clever enough) to rely on a specific aspect of the word if unsure of a memory-match, the findings suggest that AD children reverted to chance guesses when unsure of a memory match, not relying on information they may well have encoded (as suggested by their adequate phonological competence generally). This is suggested by their 'chance level' phonetic error rate (56% of all recognition-task errors). Research on younger (age 7 - 8) RD children has suggested a similar deficit in knowing when to apply efficient strategies to novel memory

tasks (Kastner & Rickards, 1974); however, this difficulty appears to resolve over time, especially with specific training (e.g., Torgeson, 1979). To explore these possibilities in somewhat more detail it would be interesting to compare the three disability groups using specific training of learning strategies (Pressley, et al., 1987; Torgeson, et al., 1979). The present results would suggest that, given a concrete strategy, the adverse effects of task novelty and semantic confusion may abate for AD children as well.

C. Nonverbal Memory Skills - Specific Aspects

The Rey-Osterrieth Complex Figure memory task allows one to compare not only the oft-studied recall/retrieval measure of mnemonic function, but also the important aspect of memory encoding (copy phase). The hypotheses made in relation to the AD group were, for the most part, supported. As predicted, the AD group was far inferior to both RD and C groups in both Copy and delayed Recall aspects of the complex figure. However, as alluded to previously in the test for Hypothesis 2(a) (comparing Verbal and Nonverbal memory performances), when the performances of all three groups are 'normalized' by using 'per cent retained' as the memory measure, a different result obtains. That is, when the memory bias against 'poor copiers/encoders' (particularly subjects in group AD) is removed, no groups are significantly different

from each other. Haith (1971) has suggested that increases in children's normal memory capacity can be attributed primarily to encoding strategies which improve naturally in the development of the child. (He further states that such strategies are not necessarily verbally-based.) The present results would thus imply a marked deficiency in AD children's information-processing abilities, as they appear to have difficulty with encoding strategies, the definitive skill of developing mnemonic function in children.

The addition of the Organization score failed to show any between-group differences. One explanation for this lack of differentiation is believed to lie in difficulties with Waber and Holmes' (1986) scoring criteria, problems often found in the quantification of qualitative clinical concepts/ratings. Indeed, these researchers report only a 51% reliability correspondence between statistically-derived quantitative scores and qualitative clinical ratings by experts.

In terms of more discrete nonverbal memory elements (the Gestalt and Internal features of the figure), analysis of the raw recall scores revealed inferior scores of both types in the AD group. The hypothesized lower Internal feature scores for the RD group (believed to be a function of their impaired verbal mediational skills) did not obtain. Similarly, after correcting for

the amount of information encoded (using 'per cent retained' scores), the predicted Gestalt/Internal dissociation did not obtain. Rather, all subjects performed significantly better in recalling Gestalt than Internal elements, a finding consistent with the reports of Waber and Holmes' (1986) normative sample on the Rey Osterrieth recall productions. It would appear, as these authors report in relation to their non-clinical sample, that older children require organizing structures for recall; perhaps, this is the form in which material is directly encoded and, thus, later retrieved from storage. The AD, RD, and C groups did not differ in the recall of Internal elements, although it is possible that a 'floor effect' occurs in children's ability to recall detailed elements in an incidental memory task, as only a limited amount of such specific features can be recalled by the average child in this age group.

While not reaching commonly-accepted levels of statistical significance, the AD group obtained the poorest retention scores overall on both Gestalt and Internal elements. This provides further evidence of their marked difficulties with both encoding and retrieval of nonverbal input (Fletcher, 1985b). It is also important to note the possible difficulties inherent in the dichotomizing of Gestalt and Internal elements (derived from Waber and Holmes' [1985, 1986] scoring methods). This difficulty is briefly illustrated in Figures 11 and 12 with characteristic AD and RD children's recall reproductions of the Rey Osterrieth Figure.

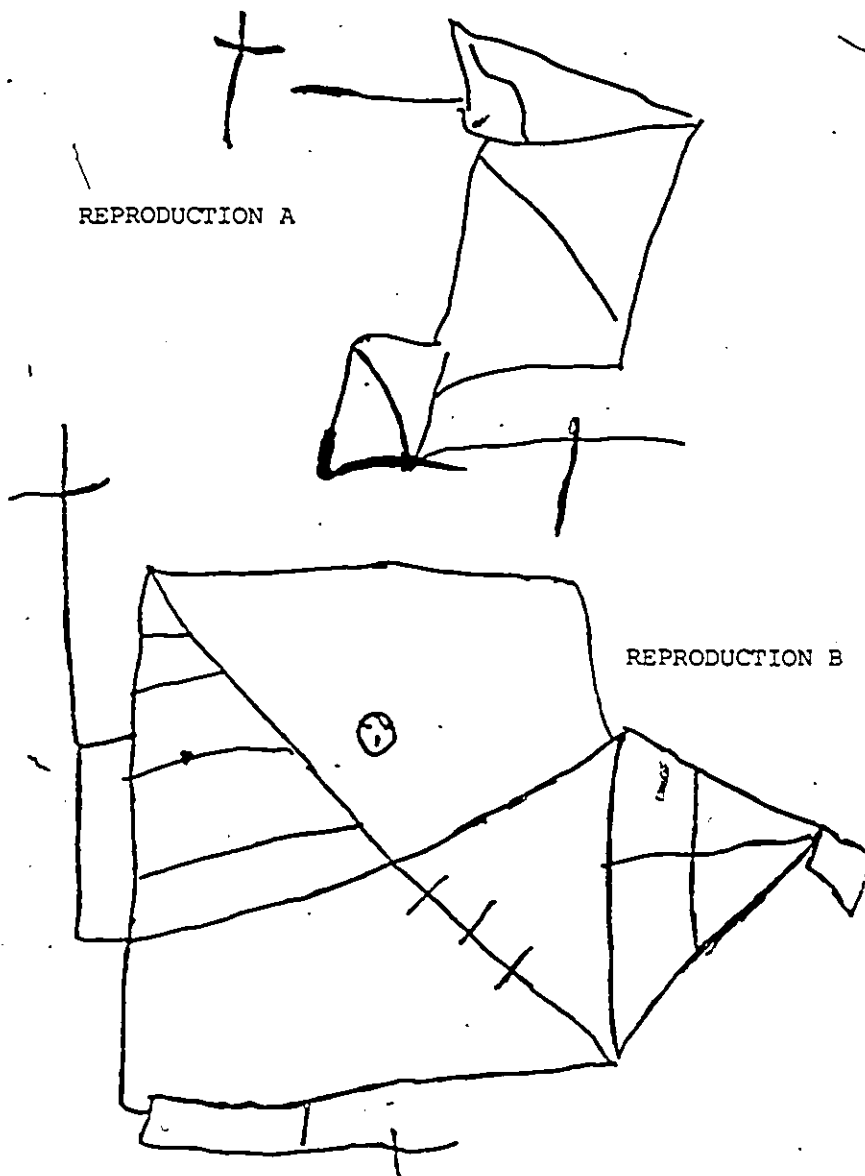


FIGURE 11 - Illustrations of Two AD Children's Rey-Osterrieth Recall Phase Productions:
These reflect varying degrees of difficulty with 'Gestalt' aspects.
According to quantitative criteria, Reproduction A scored Gestalt - 18, Internal - 1; Reproduction B scored Gestalt - 25, Internal - 6.
Compare with Figure 12.

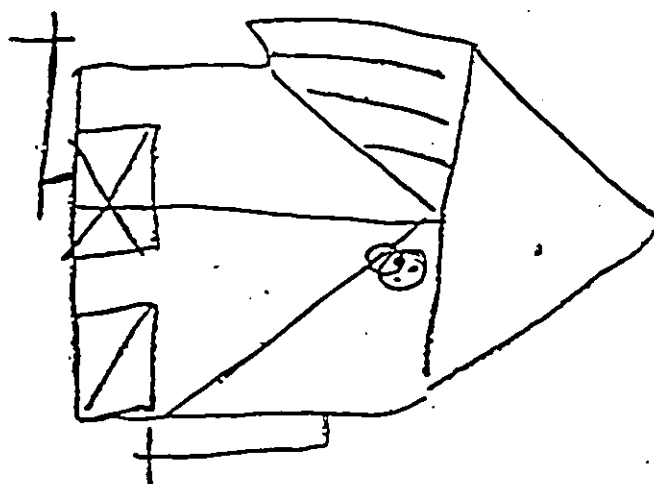
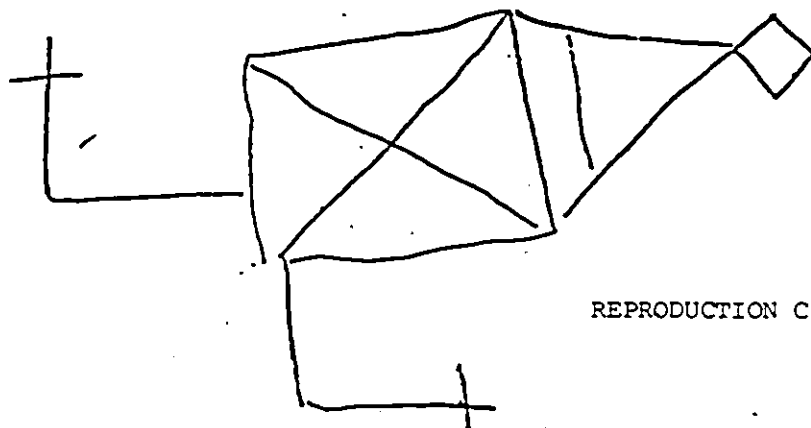


Figure 12 - Illustrations of Two RD Children's Rey-Osterrieth Recall Phase Productions:

Both suggest good preservation of 'Gestalt', varying levels of difficulty with Internal features. Reproduction C scored Gestalt - 20, Internal - 5; Reproduction D scored Gestalt - 20, Internal - 14.

As is evident, while the differences in Gestalt and Internal quantitative scores are sometimes slight, the quality of drawings may be quite marked in the 'Configuration-oriented' or 'Internal detail-oriented' directions suggested by Waber and Holmes in their clinical ratings scheme. To characterize fully these reproductions, it may be necessary to devise a 'weighted' quantitative scoring method which also accounts for severity of difficulty (e.g., more points subtracted for distorted or misplaced line segments).

The finding that the RD group equalled , and even surpassed, control subjects on the various measures of nonverbal encoding and recall is noteworthy. This clearly has been reflected in other studies which have compared RD and normal children in their abilities to recall purely nonverbal memory material, such as spatial configurations (Bauserman & Obrzut, 1981; Fletcher, 1985b), and faces and abstract designs (Holmes & McKeever, 1979; Liberman et al., 1982; Swanson, 1978). RD children have also been shown to be quite adept at making mnemonic associations between auditory and visual nonverbal stimuli (Vellutino et al., 1973). In fact, the nonverbal abilities of the RD group approaching the superior level of performance suggests a superior skill in this area, perhaps developed to this extent as a compensation for below-average verbal skills and stronger day-to-day reliance on this form of mnestic encoding and processing (Aaron, 1981). An

alternative explanation is that their above-average PIQs reflects their true superior 'learning potential' and that the lowered VIQs represents a drop in skills : "the commonly encountered situation in which a child's general learning potential is not fully realized in the academic situation because of a specific psycholinguistic deficit." (Rourke et al., 1983, p. 350)

D: Memory - Defining the Term

In the discussion of these findings, it is essential at this juncture to consider the issue of how best to define differences between groups. As is apparent from the previous research, while the general rubric 'memory' may prove useful in non-clinical situations, the various stages of encoding, storage, and retrieval, as well as the myriad related cognitive processes make it essential to clarify differences in order to make practical use of the research findings. This is clearly illustrated through the disparate results emanating from the two measures of 'phonetic ability' utilized to test Hypothesis 4 : one, the phonetic error rate on verbal recognition tasks; the other, a production score on a 'non-memory' task tapping into established phonetic codes. The results of these analyses implicated differences in general phonetic processing of information by one group (RD), while this had no effect on a phonetic memory test. Conversely, the combination of good phonetic processing on a rote task with the adverse effects of task novelty and/or semantic confusability by

another group (AD) produced quite opposite results. In this case, 'memory' task analysis as well as background clinical information on the respective groups clarified these results in somewhat more detail.

Another instance in which the 'memory' definition appears to be critical was shown in the encoding versus retention/retrieval (present results do not allow us to distinguish these final stages) aspects of the various elements of the Rey Osterrieth task. As this particular task procedure allows one to distinguish initial encoding from later 'memory' requirements, it becomes clear that it is the encoding phase per se which is problematic for the impaired group (AD). All groups were approximately equivalent in their ability to retain information already-encoded (retaining approximately 55-60% of the amount of material input). Fletcher (1985b), using Buschke's useful selective reminding technique, has also attempted to study two separate memory processes, storage and retrieval. His results suggest that AD children have both storage and retrieval difficulties with nonverbal information (somewhat in contrast to the present results, although quite distinct memory tasks are compared). This result, similar to the present study, is attributed largely to AD children's difficulties with the processing and handling of novel information for which no pre-existing cognitive strategy exists.

Further evidence of the significant impact which memory-task definition can have on a particular study or result is reflected in the support for Hypothesis 5. The Recall/Recognition format of verbal memory tasks was compared and resulted in the predictable superiority of Recognition performances by all subjects. As well, significantly better performances were achieved by control subjects than by both LD subject groups on the Recall measures only. While this appears to relate directly to the format through which test items are assessed, it is more germane to the issue of different task requirements. Why can LD children perform so much better on Recognition than Recall tasks? The answer would appear to lie in the difference between the tasks -- namely, the recall requirement of producing a response makes this an intrinsically more difficult cognitive task than simply matching templates or taking educated guesses on the recognition task. Generally, it would seem that deeper levels of encoding are required to form and maintain a response that can be later produced for recall (Craik & Lockhart, 1974). Another possibility lies in the form of response per se. For example, it may be too difficult for LD subjects to write or repeat the correct answers that they have in mind. However, the highly 'spellable' and 'repeatable' nature of the stimuli (achieved through careful pre-testing and selection of words) argues against this as a comprehensive explanation.

While there does not appear to be any direct resolution to these

task-definition difficulties (e.g., the continuing debate on single- versus dual-process theories of recall/recognition -- Zechmeister & Nyberg, 1982), the interchangeable use of these 'memory' paradigms in research, often in support of one particular line of reasoning (e.g., the phonetic encoding/confusability hypotheses tested by Alegria & Pignot, 1979; Brady et al., 1983; Mann et al., 1982) suggests that careful consideration be given to these issues. Quite separate memory or cognitive processes may be responsible for similar results between two groups; as in the present analyses, it may be most relevant to consider both similarities and differences in a single formulation. Only through careful hypothesis generation and testing can these differences be fully elucidated.

E. Neuropsychological Implications

As a whole, these test results are quite consistent with previous research conducted on the distinct learning disability subtypes of children. For the purposes of this discussion, the RD and AD groups studied will be compared, respectively, to the Group 2 and Group 3 subtypes isolated by Rourke and his associates (Rourke & Finlayson, 1978; Rourke & Strang, 1978) and discussed in other research (Fletcher, 1985b). While the specific identification criteria used here were somewhat different (e.g., Rourke and his colleagues also included cut-off scores on the WRAT Spelling subtest), the general similarities in WRAT Reading

and Arithmetic performances suggest that adequate comparisons can be made. In addition, for the RD group, the present IQ-related Verbal and Performance indices are in keeping with those of the Group 2 subtypes. However, the Verbal and Performance indices (each based on only two WISC-R subtests) suggest discrepant results when comparing the AD group (low-average Verbal, average Performance) to the low-Performance, average-Verbal Group 3 type (Rourke & Finlayson, 1978). Thus, generalization of these results to the general RD subtype can be made with greater confidence than the generalizing of these results to the larger subtype of AD children. The present AD group may, in fact, not be representative of the larger clinical subtype previously studied, although the consistency in deficient nonverbal abilities is certainly noteworthy.

The present results indicate mild deficits on certain measures of verbal memory in RD subjects, although only when tested with recall format. Phonetic indices suggest mild difficulty with the production of well-established phonetic codes, although this deficit per se does not appear to affect the sensitivity to phonetic characteristics of to-be-recognized verbal stimuli. Put another way, these children appear to possess normal strategies for novel memory situations. Conversely, in the nonverbal realm, RD children were shown to have no difficulty, relative to normals, on various nonverbal memory measures.

Generally, these test results are consistent with previous clinical descriptions of children with reading disability and relative strengths in mechanical arithmetic. On 'non-memory' tasks they frequently exhibit mild to moderate impairments in the analysis and synthesis of verbal symbolic and phonological material (Doehring, 1985; Petrauskas & Rourke, 1979), with average or better abilities in the processing of nonverbal, particularly visual-spatial information (Lyon, et al., 1981; Petrauskas & Rourke, 1979; Rourke & Finlayson, 1978). Combining the present memory test results with reports of neuropsychological performances in previous studies, support is gained for Orton's early notion of cortical dysfunction of verbal-oriented systems of the left cerebral hemisphere (1937, as discussed in Holmes & McKeever, 1975). Later researchers have also implicated dysfunction in verbal-linguistic-analytic left hemispherical systems (Obrzut, 1979; Rourke, 1982). Specifically, Jorm (1979) has hypothesized that dysfunction in the inferior parietal lobule of the left cerebral hemisphere accounts for both short-term verbal memory impairment and difficulties with decoding the printed letter and word for reading. Byrne (1981) favors an explanatory model in which limited 'linguistic access' results in both memory (mostly serialized) deficits and reading problems; the neurological determinants per se are not specifically addressed in Byrne's formulation.

The complex neuropsychological correlates of arithmetic disorders, on the other hand, include a number of nonverbal deficits, such as difficulties with processing and analyzing pictorial (Ozols & Rourke, 1985) and visual-constructional materials (Rourke & Finlayson, 1978). The results of the present study, which reflect clear and significant deficits, relative to both normal and RD children, on various aspects of nonverbal mnemonic tasks are consistent with previous reports on this subtype. This is a particularly interesting finding, as it obtained with the present sample in spite of an average Performance Index on the WISC-R.

Furthermore, the present findings suggest that AD children may encounter mild difficulties on certain verbal memory tasks, particularly when novel; such findings are consistent with the mild deficits reported on other complex, novel verbal tasks (Rourke & Finlayson, 1978; Webster, 1979). Generalized difficulties in the generation and application of novel concepts and strategies have also been reported in the literature on the AD subtype (Strang & Rourke, 1983). In contrast are these children's well-developed skills on rote verbal tasks (Rourke & Finlayson, 1978). This tendency was confirmed in the results of the phonological production task used in the present study. While the present test results are consistent with a generally-held theory (Rourke, 1982) concerning dysfunctional systems of the right

hemisphere believed to subserve visual-spatial, novel analytic, and 'holistic processing' (Reynolds, 1981) functions, a more recent formulation proposed by Rourke (1987) concerning dysfunction in connective and integrative white-matter systems of the brain may well provide a more comprehensive explanatory model.

The present results were far less robust with respect to the RD-group verbal impairments predicted. Since many of the comparisons are made with studies on younger disabled learners, these results may be suggestive of a lag in certain verbal attentional (Tarver, et al., 1976) and/or phonemic and linguistic processing (Beech & Harding, 1984; Ozols & Rourke, in press) skills among RD children which do improve, gradually, over time as neural systems mature (Satz & Van Nostrand, 1973). In contrast, the present study's evidence of AD children's more pervasive difficulties with the encoding of various types of nonverbal information indicates more serious learning impairments in this subtype. Recent reports suggest that these learning impairments extend throughout the lifespan (Rourke, et al., 1985). Further developmental studies, comparing RD and AD subtypes across various age groups, more closely mimicking 'real-life' demands, are clearly warranted.

The general consistency of the neuropsychological configu-

rations of RD and AD children found, in the present study suggests direct support for the external validation goal of this study (Fletcher, 1985a). As reflected in Fletcher's (1985b) study of LD subtypes and memory, the present evidence for verbal/nonverbal memory differences between already-classified groups validates the notion of separate and unique subtypes of these children.

F. Educational/Remedial Implications

In keeping with the original rationale of this study, the practical ramifications which these test results have on the present educational system will now be discussed. In recent years, the extension of the neuropsychological model beyond assessment into remedial strategy planning and predictive outcome has become widely recognized (Torgeson, 1986).

The clarification of specific remedial techniques is especially pertinent for both the Specific Learning Disability and regular classroom teachers who are likely to encounter both RD and AD children in their classrooms. While these children sometimes performed similarly on the memory tasks administered to them, their differential performances shown in this study, and in previous research, suggest that they may sometimes have done so for entirely different reasons. This was particularly evident on the various verbal tasks. While both RD and, to a lesser extent, AD children showed mild weaknesses relative to controls, the pattern

of RD performances suggests that they have particular difficulty with normal verbal/mnemonic organization (Dallago & Moely, 1980) or elaborative encoding through a speech code (Alegria & Pignot, 1979). AD children, in contrast, appear to have difficulty with the encoding of novel information, in spite of good phonemic coding. As well, retrieval of linguistic information appears to be particularly problematic. This was indicated by the contrast of verbal recall performances with the adequate performances on the verbal recognition tasks, in which retrieval was facilitated. On the positive side, the generation of unique test strategies and the encoding/retention of nonverbal material did not appear to be problem areas for RD subjects.

Thus, as recommended by other researchers and clinicians, fruitful remedial approaches for this age group should ideally be designed for their specific configuration of strengths and weaknesses (Lyon et al., 1981; Rourke et al., 1983). The remedial techniques to be discussed require a careful individualized program, a recognized need in the newly revised educational system (Torgeson, 1987). Along these lines, Rourke et al. (1983) have discussed the need to consider the child's age, his/her level of motivation, and the qualities of the teacher/therapist in planning and evaluating remedial techniques. Furthermore, it is important to examine developmental issues in planning and recommending remedial approaches; for example, a child's

developmental level at a given age may dictate the abandonment of strategies focused at attacking areas of weakness, opting instead for more practical interventions which emphasize strengths and compensatory strategies. Due to the age group considered in the present study, the following recommendations are primarily aimed at remediation via compensatory strategies, a method supported by many professionals working with older LD children:

The strongest argument [against 'attacking the weakness'] is the stress and anxiety created in the child by focusing on the child's poorest abilities - the areas in which failure has most frequently occurred. Such an inherently unpleasant focus for a remedial program surely cannot be in the child's best interest ... A remedial approach to a child's learning problems needs to be based on abilities that are sufficiently intact in the child ... In the language of Luria, it is necessary to locate an intact complex functional system capable of taking over and moderating the learning processes that are necessary for acquiring the academic skills in question.

(Hartlage & Reynolds, 1981, p. 358)

In this connection, Rourke (1983) strongly recommends careful testing of the "sequencing and timing of remedial programming" for various subgroups of disabled learners. The growing body of evidence suggesting the presence of unique subtypes among RD and multiple learning disabled children clearly warrants comprehensive individualized assessment before application of such

techniques, as well as ongoing interaction between re-evaluation and treatment phases (Rourke, 1976).

Therefore, the following approaches are proposed for RD children with respect to mnemonic functions:

(1) As neither sensory modality, auditory or visual, appears to be particularly superior for the presentation of verbal material (as the only modality-specific weaknesses appeared on span-type and dichotic/tachistoscopic tasks which do not mimic everyday memory demands), McGrady and Olson's (1970) suggestion to abandon perceptual training in favor of training children to make better use of encoding strategies gains support. This would include allowing more time to encode verbal information. Other studies have suggested, along these lines, that verbal attention might be aided by reducing external stimulation and 'activity' in the same modality channel (Brooks, 1968). Contrary to popular practice, 'multi-modal input' alone does not appear to benefit RD children as much as normals (Bruning, et al., 1978). In addition, despite the effort made in the present study in the ordering of tasks (alternating visual and auditory presentations), at least one study suggests that switching modalities does not produce the normal 'release from proactive inhibition' in RD subjects (Farnham-Diggory & Gregg, 1975). Thus, it would appear unnecessary for remedial teachers to direct specific attention at

the modality (auditory or visual) in which verbal memory tasks are presented when planning for RD children.

(2) Specific training in 'short cuts' for the encoding of linguistic information (Bauer, 1979; Torgeson, 1979) would appear to be fruitful. Techniques such as chunking (Dallago & Moely, 1980), elaborative semantic rehearsal (Torgeson et al., 1979), and distinguishing relevant from irrelevant facts (Oakhill, et al., 1983) have been shown to produce positive results and are consistent with the evidence relating to RD children's intact semantic stores (Wiig & Roach, 1975) and other adaptive abilities of these children (e.g., conceptual grouping skills). In light of these children's specific difficulties with the retention of letter strings for encoding/decoding purposes, it would seem useful to emphasize the encoding of letter chunks such as vowel digraphs (e.g., oo, oi) and word affixes (e.g., ment, ing) to promote 'holistic' learning and reduce the processing demands of the visual memory-phonemic memory system (Samuels, 1987).

(3) Whenever possible, the results of the present study suggest that it would be useful to train RD children to exploit their relative strengths in nonverbal areas. This might involve encouraging them to draw pictures or diagrams to illustrate complex verbal concepts and material (thereby recoding the information via the 'visual scratch pad'). The increased use of

microcomputers in the school system also provides an excellent alternative to teachers and students for designing visual presentations of material and lessons. Training RD students in the use of visual imagery mnemonics as an alternative to verbal encoding with specific types of material may also be helpful (Lorayne, 1985; Pressley, et al., 1987; Seamon & Gazzaniga, 1973). The results of an RD memory study by Bayliss and Livesey (1985) underscores this need to teach children to utilize their 'preferred' cognitive strategies in order to maximize individual performance.

Recent studies have revealed that the 'keyword mnemonic' system, a combined verbal-visual imagery mnemonic approach, can be an extremely helpful and effective strategy for RD children to use in learning various types of academic material, including vocabulary-definition associations (Condit, et al., 1986) and scientific facts (Mastropieri, et al., 1985). Long-term retention using this strategy appears to be quite good. Furthermore, unlike other recommended strategies, the practical benefits in an applied (classroom) setting have been demonstrated directly (Condit, et al., 1986).

The AD children's similar lowered performances on certain verbal recall tasks suggest that elaborative encoding mechanisms may be faulty and that specific training in these skills, as with RD children, would be useful. As with the RD group, perceptual

training, favoring one modality over another, does not appear to be a useful aid to memory in the 10 - 14 year age group. In contrast, AD children's performances on other memory tasks implies that the verbal 'memory' problems are not linguistically or phonetically-based, but rather appear to lie in the poor application of test strategies and in dealing with novel information efficiently. Their memory task performances suggest a deficiency in a normal developmental trend, that of relating "learning strategies to changing recall task demands" (Belmont & Butterfield, 1971). Thus, more specific remedial approaches (apparently not needed by most RD or normal children) appear to be required by this LD subtype. These approaches should emphasize their well-developed rote verbal and phonological processing skills:

(1) AD children would likely benefit from practice and training in a careful, step-by-step approach in which they review available test strategies and choose the best alternative. Pressley and his colleagues (1987) have discussed extensively the LD child's need for learning new strategies, as well as learning how and when to utilize each strategy effectively; they refer to this latter area as 'metastrategic knowledge'. These authors further compare the training methods of 'direct explanation' -- a teacher-directed presentation of the strategies; versus 'dyadic instruction' -- a method dependent on direct interaction of the students and teacher

in experimenting with new strategies. This latter type of active, experiential approach, while it may pose initial difficulties for the AD child who is accustomed to a more withdrawn, non-interactive role (suggested in Strang & Rourke, 1983, 1985a), would likely lead to greater learning of strategies and metastrategic information.

(2) These children's difficulties in encoding, particularly of novel and nonverbal information, suggest that they would benefit from more time to encode information, carefully re-coding it through verbally-mediated strategies (as suggested in Strang & Rourke, 1985a, in reference to remediation of socio-emotional coping difficulties). In the learning of new verbal material, an information processing technique known as 'semantic mapping', in which words are related to super-ordinate and subordinate examples within the child's lexicon, would likely be a beneficial aid to this subtype of verbally-competent learners.

As novel information appears to pose specific difficulty for this group of children, behavioural methods of gradual stimulus desensitization may also be of use. This might be facilitated by presenting smaller units of novel material, drawing parallels to already-learned/encoded facts and concepts. A secondary benefit of anxiety reduction may also result (Lachenmeyer & Gibbs, 1982).

(3) When dealing with largely nonverbal (e.g., pictorial) information, these children would likely profit from training in talking their way through such tasks, labelling and listing information in highly redundant, sequential steps. This should aid in circumventing general difficulties with organization of material to-be-encoded (Farnham-Diggory, 1978; Rourke & Strang, 1983). Hicks (1980) has demonstrated the utility of such training in improving visual recall scores for both RD and normal readers. Verbal mnemonic strategies, such as first-letter cuing (Lorayne, 1985), may also be helpful as a means of exploiting their rote phonological and verbal symbolic abilities. As many younger AD children exhibit writing as well as arithmetic deficits, AD children who persist in having such difficulties may benefit from reliance on tape recorders to supplement verbal memory while circumventing writing difficulties (Siegel & Feldman, 1983). Older AD children may encounter difficulty when required to align or visually organize written material and therefore may also benefit from recoding it into its oral form (Strang & Rourke, 1985b).

The future directives for research on these children clearly should include testing of these and other remedial recommendations through specific controlled studies. A developmental framework would also be most useful, as many tests results, including the present, suggest changing patterns of

ability throughout the school years. The challenge which these children's unique learning needs present to the educational system is great and warrants close consideration from the various disciplines of learning.

REFERENCE NOTES

1. Ontario Ministry of Education and Ministry of Colleges and Universities. Bill-82: An Act to Amend the Education Act, 1974. Toronto: The Queen's Printer for Ontario, 1980

2. When the Education Act, 1974 of Ontario was amended recently to accommodate disabled students in a mainstreaming rather than segregated format, Bill 82, which introduced these amendments, identified the students who are unable to profit from standard instruction as "hard to serve" pupils.

3. The Deviation Quotient was obtained from the WISC-R short-form through the following method: The six correlations (found in Table 14, WISC-R Manual) between combinations of the subtests used (Information, Vocabulary, Picture Arrangement, Block Design) were summed for each age group. This value was then compared to those in Table C-26 (Sattler, 1982, reprinted from Tellegen & Briggs, 1967) to determine the appropriate constants (a and b) for use in the Deviation Quotient Formula : $(\text{Composite score of 4 subtests} \times a) + b$. An estimate of Full Scale IQ was thus determined for each subject individually.

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Appendix A

DEFINITION OF SPECIFIC LEARNING DISABILITIES

Ontario Ministry of Education Definition of Specific Learning Disability (used by school boards):

"A learning disability is

a learning disorder evident in both academic and social situations that involves one or more of the processes necessary for the proper use of spoken language or the symbols of communication, and that is characterized by a condition that:

a) is not primarily the result of:

- i) impairment of vision;
- ii) impairment of hearing;
- iii) physical handicap;
- iv) mental retardation;
- v) primary emotional disturbance; or
- vi) cultural differences;

b) results in a significant discrepancy between academic achievement and assessed intellectual ability, with deficits in one or more of:

- i) receptive language (listening, reading);
- ii) language processing (thinking, conceptualizing, integrating);
- iii) expressive language (talking, spelling, writing);
- iv) mathematics computations;

c) may be associated with one or more conditions diagnosed as:

- i) a perceptual handicap;
- ii) a brain injury;
- iii) minimal brain dysfunction;
- iv) dyslexia;
- v) developmental aphasia.

Source: Metro Separate School Board of Toronto, Handbook of Special Services, MSSB.

Validation Copy - Sept., 1985. Rev. E.F. Boehler, Chairman.

Appendix B

VERBAL, NONVERBAL TASK STIMULI

List of Words Comprising Various Verbal Conditions in this Study

1. VERBAL LIST A - Visual presentation - Recall format

DOWN	SAID
HERE	GOOD
SOON	HAVE
LIKE	THAT
WELL	BLACK

2. VERBAL LIST B - Auditory presentation - Recall format

HELP	ROAD
BACK	EACH
PLAY	WISH
MORE	LEARN
SHALL	THREE

3. VERBAL LIST C - Visual presentation - Recall format

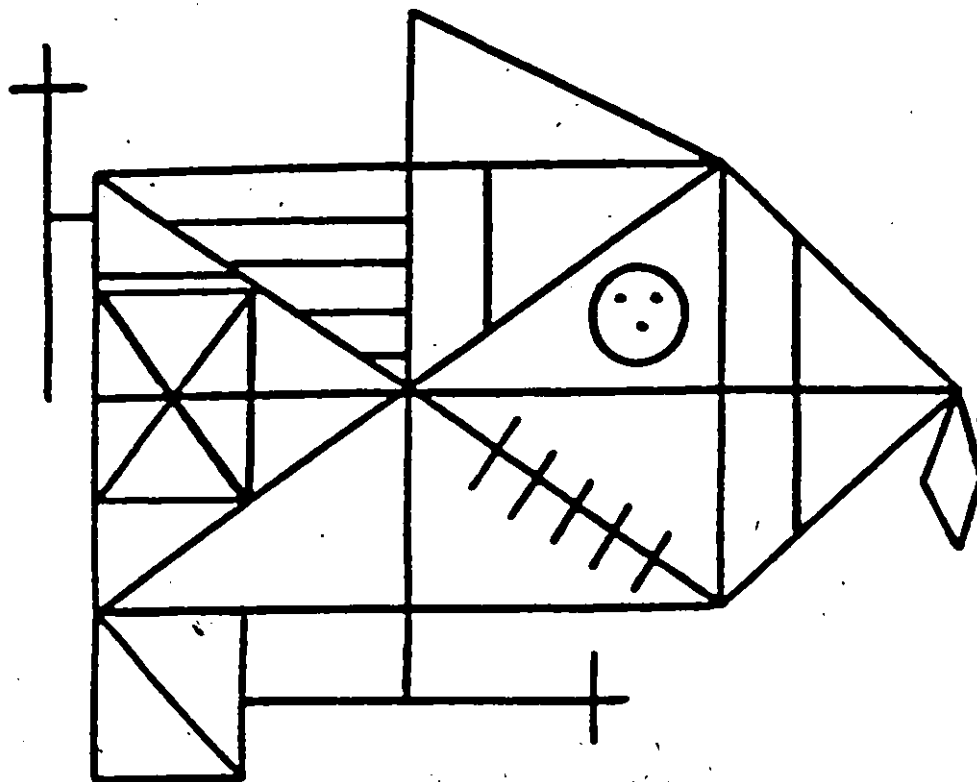
BEST	HAND
KEEP	LOST
NEXT	ROOM
WORK	THINK
GREEN	START

4. VERBAL LIST D - Auditory presentation - Recognition format (First word is target, second is rhyming foil, third is distractor)

MUCH-SUCH-READ	LINE-FINE-SAID
FOUR-YOUR-WHAT	WHEN-THEN-KNOW
SAME-CAME-GIRL	GREAT-STATE-CHILD
NEAR-DEAR-LATE	COULD-WOULD-DRESS
WILL-FILL-MARK	THERE-WHERE-HORSE

5. VERBAL LIST E - Visual presentation - Recognition format

LOOK-BOOK-PASS	COME-SOME-DROP
HOLD-TOLD-REST	MUST-JUST-LAND
SEEN-MEAN-FOOD	TAKE-MAKE-STOP
FIND-KIND-THEM	MIGHT-RIGHT-YOUNG
CALL-FALL-GOOD	GIVE-LIVE-NAME



Nonverbal Memory Task : Rey Osterrieth Complex Figure

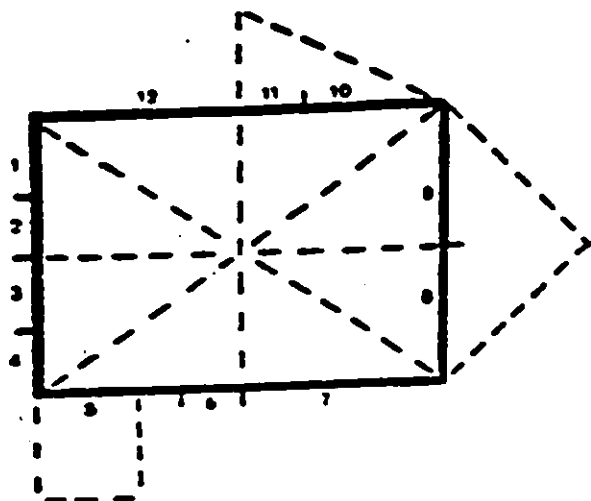
Appendix C

REY-OSTERRIETH COMPLEX FIGURE SCORING CRITERIA

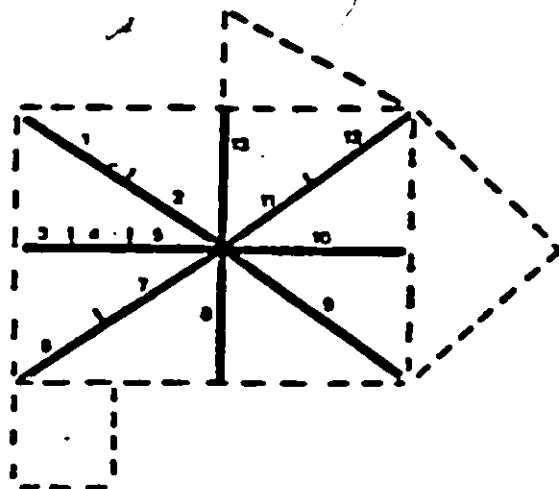
Scoring Criteria for Levels of Organization - Rey Osterrieth Figure

- Level I: Any design that does not satisfy criteria for Level II.
- Level II: (1) Upper and lower left corner of base rectangle;
(2) Left side of base rectangle aligned;
(3) Lower horizontal of base rectangle aligned at the middle;
(4) Lower horizontal aligned at lower left box or middle horizontal aligned at left center box or upper horizontal aligned.
- Level III: (1) Upper and lower left corner of base rectangle;
(2) Lower right corner of base rectangle;
(3) Four sides of base rectangle aligned;
(4) Middle vertical aligned at center or middle horizontal aligned at left center box or main horizontal and vertical intersect or main diagonals intersect.
- Level IV: (1) Upper and lower left corner of base rectangle;
(2) Lower right corner of base rectangle;
(3) Four sides of base rectangle aligned;
(4) Diagonals of base rectangle intersect;
(5) Main horizontal and vertical intersect or middle vertical aligned at center or middle horizontal aligned at left center box.
- Level V: (1) Four corners of base rectangle aligned;
(2) Four sides of base rectangle aligned;
(3) Main horizontal and vertical aligned;
(4) Diagonals aligned;
(5) Horizontal, vertical, and diagonals intersect.
-

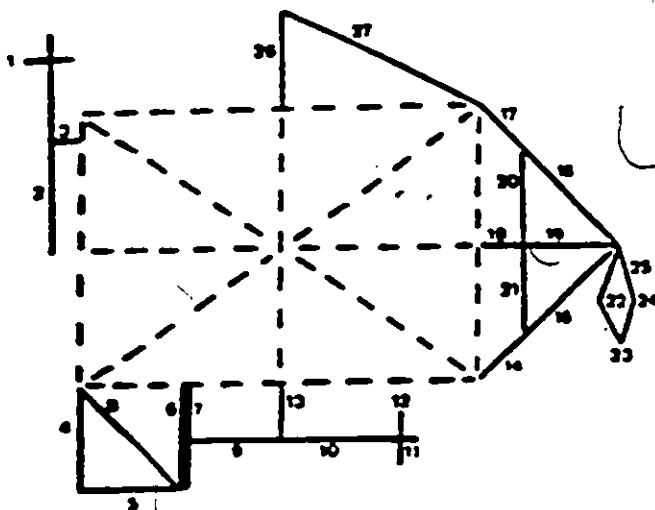
A



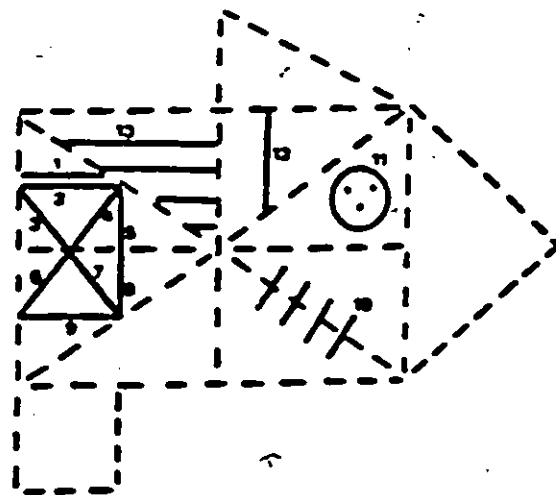
B



C



D



Key Osterrieth Complex Figure Scoring Criterion
 Diagrams A, C = Gestalt Features
 Diagrams B, D = Internal Features
 Adapted from Waber & Holmes, 1986.

Appendix D

ANOVA SUMMARY TABLES - MEMORY TASK ANALYSES BY GROUP

Summary of Repeated Measures ANOVA Verbal-Nonverbal Type Task x Group

Source	SS	df	MS	F
Group	188.39	2	94.11	.91
Task Type	4.62	1	4.62	.05
Group x Task	272.73	2	136.36	1.55
Error	4478.51	51	87.81	

Summary of Repeated Measures ANOVA Auditory-Visual Modality of Task x Group

Source	SS	df	MS	F
Group	24.86	2	12.43	2.01
Modality	.94	1	.94	.18
Group x Modality	1.16	2	.58	.11
Error	264.92	51	5.19	

Summary of Simple ANOVA Copy Accuracy Rey-Osterrieth Task Across Groups

Source	SS	df	MS	F
Group	367.38	2	183.69	9.40****
Error	996.10	51	19.53	
Corrected Total	1363.48	53		

Summary of Simple ANOVA Recall Accuracy Rey-Osterrieth Task Across Groups

Source	SS	df	MS	F
Group	722.53	2	361.27	4.27*
Error	4311.17	51	84.53	
Corrected Total	5033.70	53		

*p < .05, **p < .01, ***p < .005, ****p < .0005

Summary of Simple ANOVA Rey-Ost. Recall Organizational Scores Across Groups

Source	SS	df	MS	F
Group	1.12	2	.56	.44
Error	65.59	51	1.29	
Corrected Total	66.71	53		

Summary of Repeated Measures ANOVA Gestalt-Internal Feature Rey-Ost. Recall x Group

Source	SS	df	MS	F
Group	1839.80	2	919.90	2.10
Feature Type	303.55	1	303.55	32.15****
Group x Feature	431.92	2	215.96	.84
Error	13170.69	51	258.25	

Summary of Simple ANOVA Percentage Phonetic Errors Across Groups

Source	SS	df	MS	F
Group	3507.25	2	1753.62	2.52
Error	34073.83	49	695.38	
Corrected Total	37581.08	51		

Summary of Simple ANOVA Rhyme Production Task Across Groups

Source	SS	df	MS	F
Group	303.99	2	151.99	3.45*
Error	2245.94	51	44.04	
Corrected Total	2549.93	53		

Summary of Repeated Measures ANOVA Recall-Recognition Format of Task x Group

Source	SS	df	MS	F
Group	28.15	2	14.07	2.21
Format	612.36	1	612.36	168.33****
Group x Format	36.65	2	18.33	5.04*
Error	185.53	51	3.64	

VITA AUCTORIS

Clare F. Brandys was born on August 8, 1960 in Chicago, Illinois. In June, 1978 she graduated valedictorian from Dixon High School in Dixon, Illinois. In September, 1978, she enrolled at Loyola University of Chicago. She graduated with a Bachelor of Science, magna cum laude, in Psychology and English in January, 1982 and continued in the graduate psychology programme at Loyola University in the Spring of 1982. In September, 1982 she enrolled in the Doctoral programme in Clinical Neuropsychology at the University of Windsor, completing her Master of Arts in September, 1984. She has completed internships in neuropsychology at Henry Ford Hospital, Detroit, Michigan; the Regional Children's Centre, Windsor, Ontario; Sacred Heart Child and Family Centre, Scarborough, Ontario; and at St. Michael's Hospital in Toronto, Ontario where she is presently employed as Research Coordinator.